

DRA

# Auxiliary Payload Power System Study For Space Processing Applications Payloads

(NASA-CR-150269) AUXILIARY PAYLOAD POWER  
SYSTEM STUDY FOR SPACE PROCESSING  
APPLICATIONS PAYLOADS. PRELIMINARY  
REQUIREMENTS STUDY (McDonnell-Douglas  
Astronautics Co.) 84 p HC A05/MF A01

N77-24160

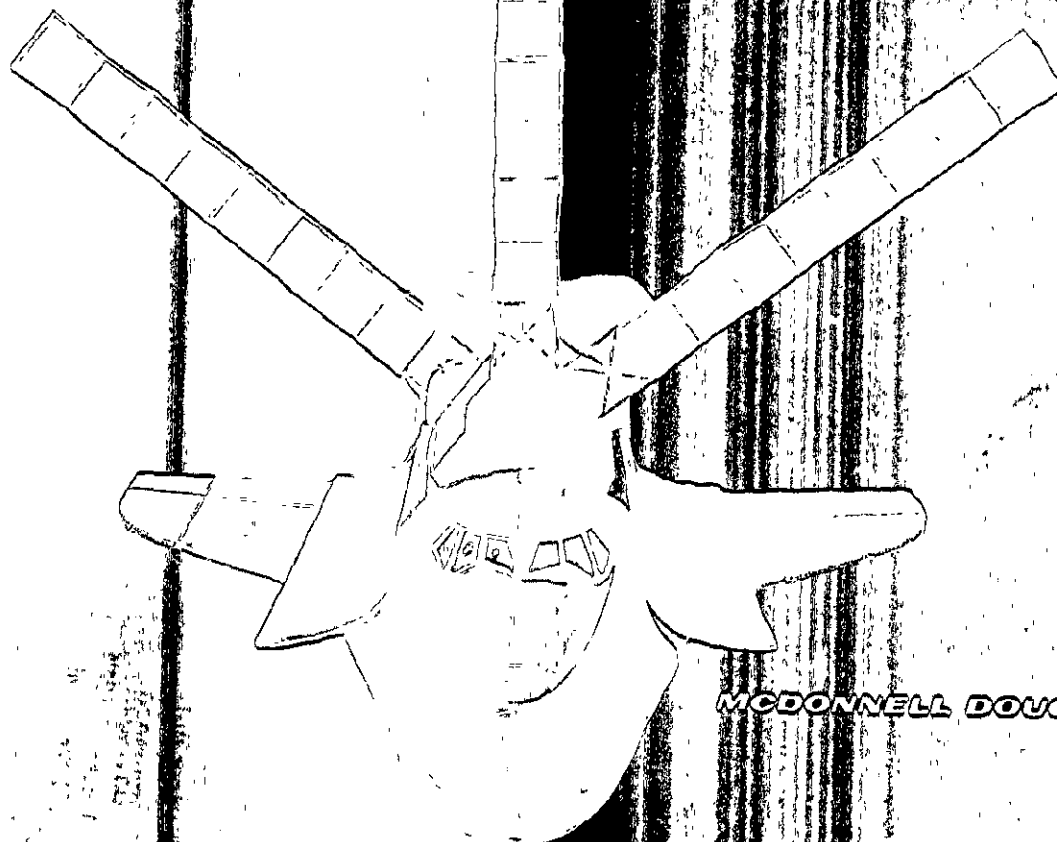
Unclas

G3/12 15592

## PRELIMINARY REQUIREMENTS REVIEW

Contract No. NAS 8-31361

JULY 1976



MCDONNELL DOUGLAS ASTRONAUTICS COMPANY - EAST

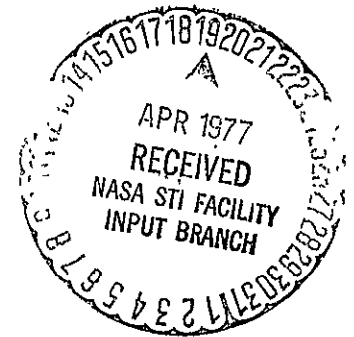
MCDONNELL DOUGLAS  
CORPORATION

# **Auxiliary Payload Power System Study**

## **For Space Processing Applications Payloads**

### **PRELIMINARY REQUIREMENTS REVIEW**

**Contract No. NAS 8-31361**  
**JULY 1976**



**MCDONNELL DOUGLAS ASTRONAUTICS COMPANY - EAST**

*Saint Louis, Missouri 63166 (314) 232-0232*

**MCDONNELL DOUGLAS**



## PREFACE

The purpose of this study is to develop the preliminary designs, specifications and programmatic data for the Auxiliary Payload Power System (APPS) as required for the initiation of the system's final design and fabrication. The APPS concept has been defined as an independent system to be carried in the Orbiter's cargo bay having the capability of housing and supporting Space Processing Applications (SPA) experiment payloads and augmenting Spacelab power and heat rejection capabilities as required in the performance of these experiments.

This briefing was prepared to support an APPS Preliminary Requirements Review. The review is required as part of the APPS Phase II effort being performed under Contract NAS 8-31361 for Marshall Space Flight Center. The Phase II effort is for 3 months duration and the PRR occurs at approximately the two thirds point in the study.

Requests for information concerning this study activity should be directed to:

James W. Poe  
NASA Marshall Space Flight Center  
Attn: PF11  
Huntsville, Ala 35812  
Telephone: (205) 453-2511

John Jasin  
McDonnell Douglas Astronautics Company  
Attn: Bldg 106, Mail Stop 409  
St. Louis, MO 63166  
Telephone: (314) 232-6651

THIS PAGE INTENTIONALLY LEFT BLANK

**A**UXILIARY  
**P**AYLOAD  
**P**OWER  
**S**YSTEM

# INTRODUCTION



## PHASE II TASKS

The Phase II activity is an extension of the Phase A activity performed by McDonnell Douglas Astronautics Company-East (MDAC-E) for MSFC under contract NAS 8-31361. The Phase A design concept is documented in the Phase A Final Report - MDC Report Number E1466 Volume III E - Further Definition of Final Baseline APPS - Task V.

The Phase II study uses the above report as the point of departure to provide the preliminary design, specifications, and programmatic definition required for supporting the final design and fabrication of the APPS. The study consists of three interrelated tasks as shown on the facing page. Task I defines APPS' requirements and interfaces. Task II develops a preliminary contract end/item specification (CEI) Part I using the format in MSFC Manual MM 8040.12 - Standard Contractor Configuration Management Requirements, MSFC Programs as a guide. Task III prepares the costs, schedules and plans that are to be used for programmatic control of the design, development, production and operation of the APPS.

## PHASE II TASKS

*The outputs from Phase II provide the definition required for supporting the final design and fabrication of the APPS*

### **TASK I — APPS PRELIMINARY DESIGN**

- **SYSTEM PRELIMINARY DESIGN**
- **INTERFACE DEFINITION  
TO ORBITER  
TO SPA EQUIPMENT  
TO GSE**

### **TASK II — APPS SPECIFICATIONS**

- **CEI SPECIFICATION — PART I (PRELIMINARY)**
- **PRELIMINARY REQUIREMENT REVIEW (PRR)**

### **TASK III — PROGRAMMATICS**

- **COSTS/SCHEDULES**
- **ENGINEERING & DEVELOPMENT**
- **PROCUREMENT APPROACH**

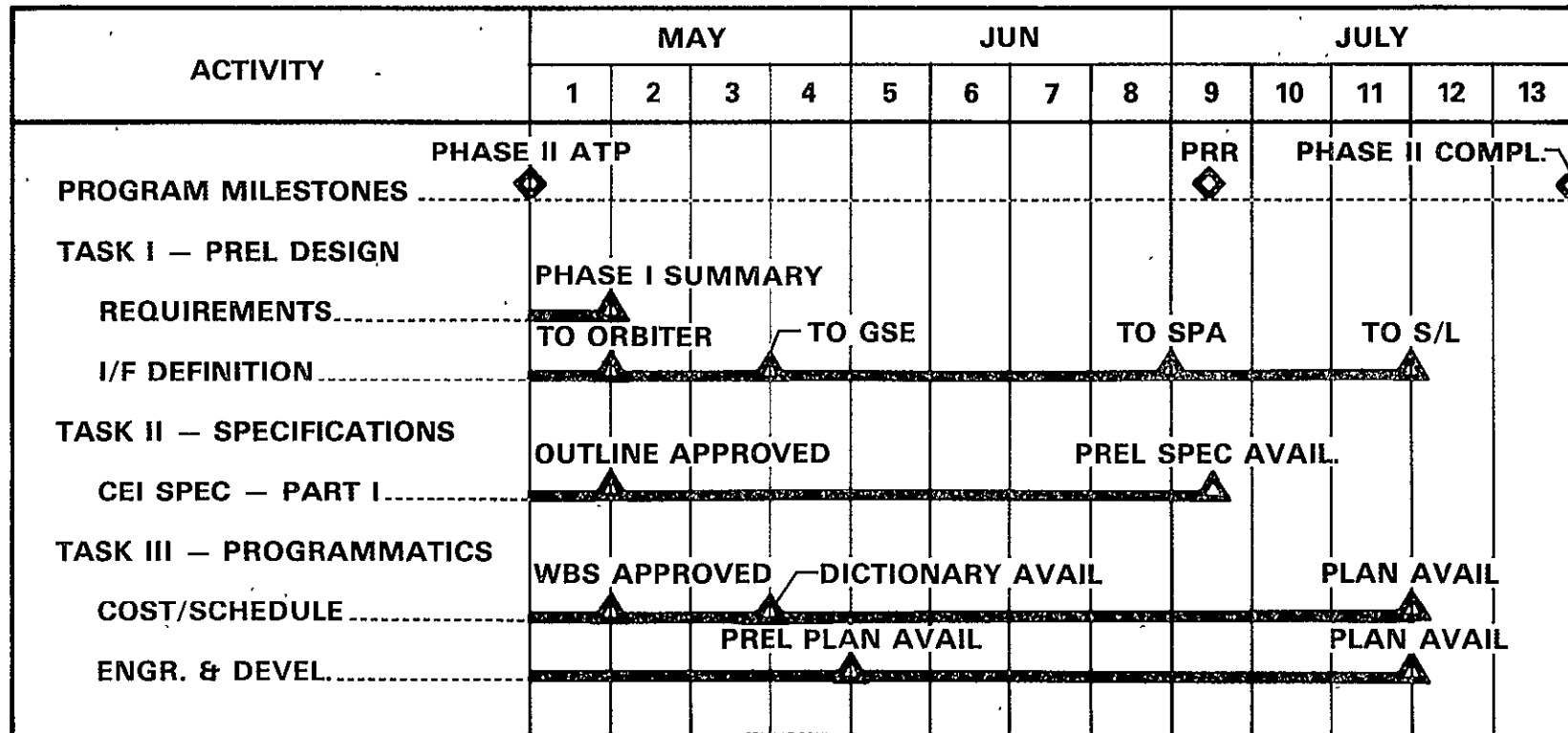
## PHASE II SCHEDULE

The schedule for the Phase II activity is shown on the facing page. The efforts for the three tasks span the three month study duration. Attention has been given to the task inter-relationships as well as the major study milestone, the Preliminary Requirements Review (PRR). Key study milestones for each task's activity are also shown.



## PHASE II SCHEDULE

*The Phase II activity is scheduled for three months duration*



## PHASE II ORGANIZATION

The MDAC-E Phase A study team developed a baseline concept of the APPS to house and support space processing payloads and to augment Spacelab power and heat rejection capabilities as required in the performance of these experiments. The same study team, under the direction of Mr. John Jasin, is performing the Phase II tasks to insure continuity of effort.

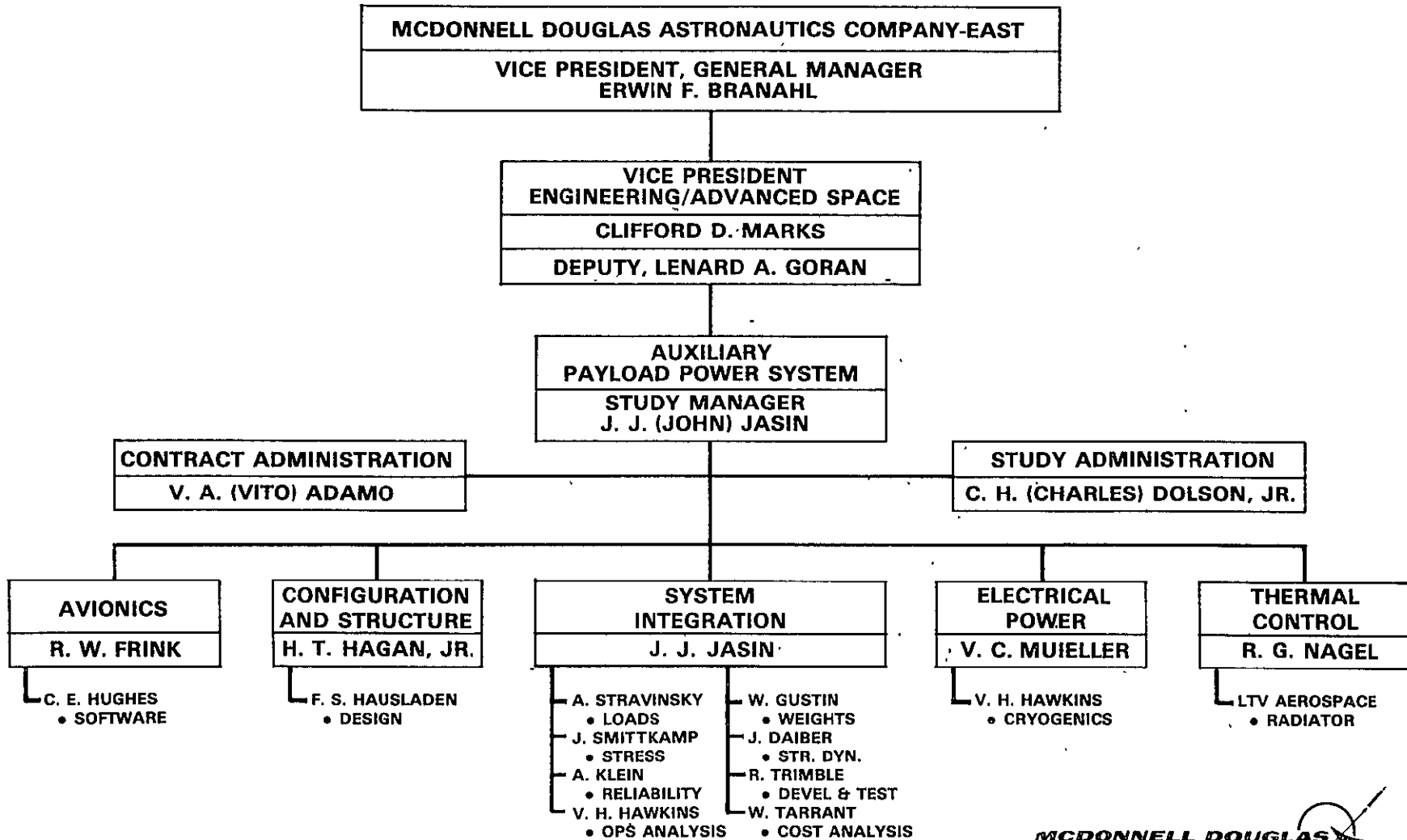
Key members of the MDAC study team are responsible for the functions shown on this chart. Bob Frink is responsible for the avionics subsystem including instrumentation, control and data management. Ted Hagan is responsible for the configuration structural analyses and design activities. John Jasin, in line with his responsibilities for integrating the total study, manages the functional lines. Vern Mueller is responsible for electrical power generation and distribution. Bob Nagel is responsible for active and passive thermal control including overseeing the LTV support work on the space radiator.

Personnel for this study have been selected so that their specific professional capability is matched to the technical task at hand. These personnel are supported by others within the advanced space effort at MDAC but not necessarily on a full time basis.

AUXILIARY  
PAYLOAD  
POWER  
SYSTEM

## PHASE II ORGANIZATION

*Our organization is structured to address the five major areas of effort*



MCDONNELL DOUGLAS  
CORPORATION

## PRR AGENDA

The Preliminary Requirements Review (PRR) is the earliest technical review of the various concepts considered and of the concept selected to meet the mission objectives. The agenda on the facing page has been established to accomplish the following objectives:

- a. The compatibility of the proposed CEI detail performance and design requirements with the Program (Project) Specification shall be established.
- b. The rationale of the selected configuration approach for the system/CEI with mission objectives.
- c. The System/CEI suitability of the selected configuration by reference to drawings, study reports, models, sketches, etc.
- d. The expected suitability of the System/CEI configuration to meet the required schedule.
- e. The feasibility and development tests required to select and substantiate design approaches.
- f. Operational requirements generated by the selected configuration and design concept.

The PRR agenda will be presented in two parts. The first will be a summary overview for general purpose information. The overview will be followed by splinter group meetings in those areas that require further discussion.

## PRR AGENDA

*The subjects contained in this briefing are*

- INTRODUCTION
- CEI SPECIFICATION/LEVEL I REQUIREMENTS
- APPS SUBSYSTEM REQUIREMENTS
  - AVIONICS
  - ELECTRICAL POWER
  - THERMAL CONTROL
  - STRUCTURE/MECHANICAL
- SCHEDULE
- VERIFICATION
- SUMMARY

THIS PAGE INTENTIONALLY LEFT BLANK

**A**UXILIARY  
**P**AYLOAD  
**P**OWER  
**S**YSTEM

# **REQUIREMENTS**

**PRECEDING PAGE BLANK NOT FILMED.**



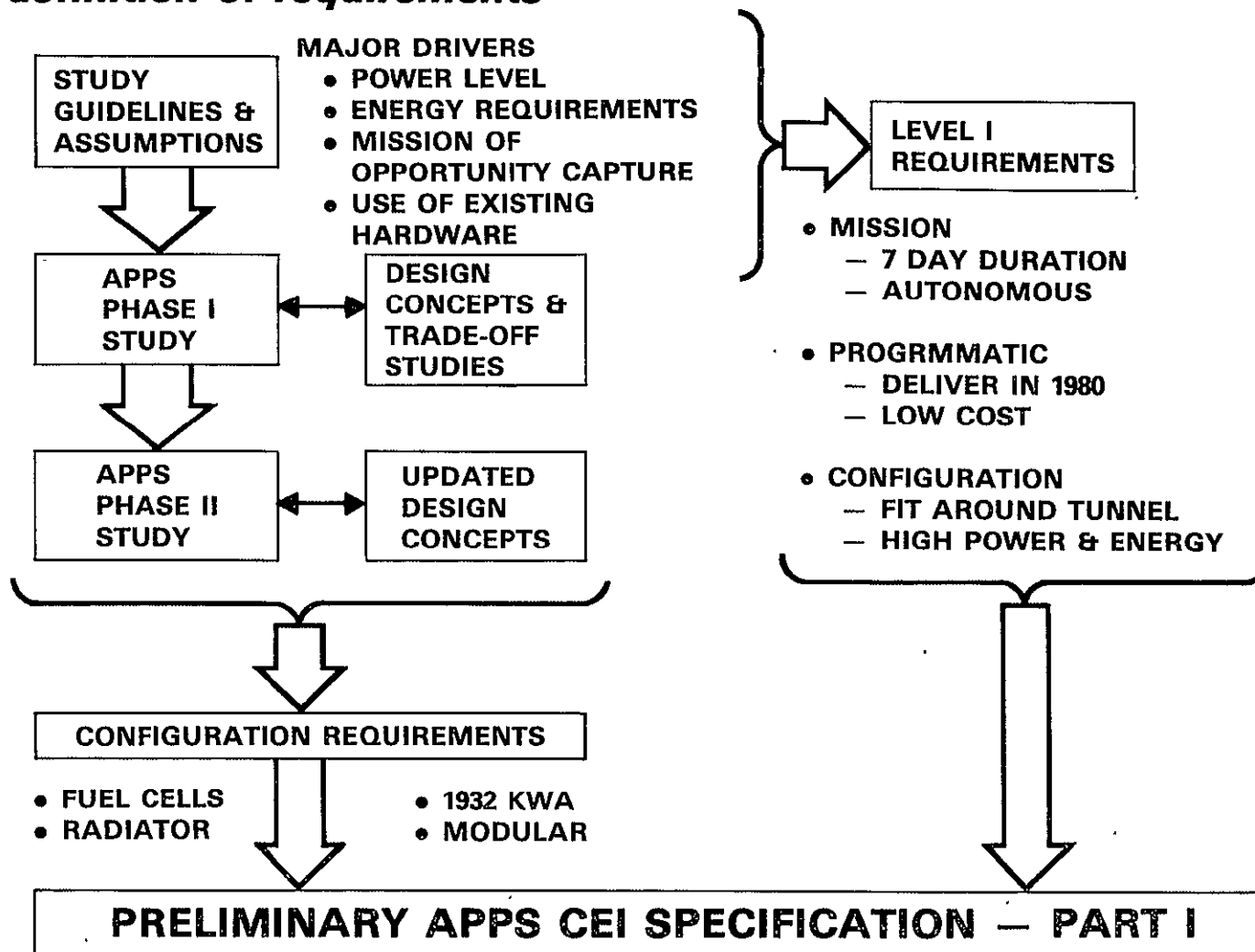
## APPS REQUIREMENTS EVOLUTION

The preliminary APPS CEI specification reflects performance requirements as evolved during the Phase I and II study efforts. During the Phase I study, those guidelines and assumptions formulated by NASA and MDAC-E were used to arrive at a baseline design concept. Following definition of the preliminary baseline design, alternate design concepts were traded-off and a final baseline design concept was selected. Definition of the final baseline design in greater detail followed. In the Phase II study, we have continued to update the design concept as better information becomes available and, in particular, to reflect the improved APPS/SPA experiment interface definition. The preliminary APPS CEI specification incorporates requirements identified in the course of the APPS study as well as those imposed as level I mission, programmatic, and configuration requirements.



# APPS REQUIREMENTS EVOLUTION

***Preliminary APPS specification resulted from the orderly definition of requirements***



## MISSION REQUIREMENTS

The primary objective of the APPS is to provide for frequent and low cost space processing experimentation. In order to provide for frequent flight opportunities, the APPS is modularized to provide selection of weight, length, power, and energy commensurate with a wide variety of SPA experiment complements and compatible with shared Shuttle payloads. Autonomy of operation to the maximum degree feasible has been a design goal to minimize impact on Shuttle operations. Shuttle type or other developed hardware has been utilized where possible to reduce costs. The APPS design is compatible with missions of 7 days duration.

## MISSION REQUIREMENTS

*The purpose of the APPS is to provide for frequent and low cost space processing experimentation*

- THE APPS SHALL ACCOMMODATE SPA EXPERIMENTS ON MISSIONS OF UP TO 7 DAYS DURATION
- THE APPS SHALL BE DESIGNED FOR A HIGH PROBABILITY OF MISSION SUCCESS
- THE APPS SHALL BE CONFIGURED TO CAPTURE A MAXIMUM NUMBER OF MISSIONS OF OPPORTUNITY
- THE APPS SHALL BE AUTONOMOUS TO THE MAXIMUM EXTENT PRACTICAL

## PERFORMANCE REQUIREMENTS

Performance requirements for the APPS are listed on the facing page. The modular design concept permits accommodation of a variety of payloads from the standpoint of installation weight and volume as well as power and energy. The APPS design utilizes Shuttle type or other developed hardware where possible to reduce cost and development risk.

## PERFORMANCE REQUIREMENTS

- **EXPERIMENT PAYLOAD ACCOMMODATIONS(DESIGN GOAL)**
  - **POWER GENERATION & HEAT REJECTION MODULE** — **1300 LB TOTAL WEIGHT**  
**200 FT3 TOTAL VOLUME**
  - **DELTA ENERGY MODULE** — **2700 LB TOTAL WEIGHT**  
**430 FT3 TOTAL VOLUME**
- **POWER AND ENERGY**
  - **CONTINUOUS POWER RATING** — **14 KW**
  - **ENERGY LEVEL** — **UP TO 1932 KWH**
- **THERMAL CONTROL**
  - **SPA EXPERIMENT HEAT LOAD** — **10 KW**
- **AVIONICS**
  - **OPERATIONAL MODE** — **HIGHLY AUTONOMOUS**
- **MAXIMIZE USE OF EXISTING/PLANNED FLIGHT HARDWARE**
  - **COMMONALITY WITH SHUTTLE**

THIS PAGE INTENTIONALLY LEFT BLANK

**A**UXILIARY  
**P**AYLOAD  
**P**OWER  
**S**YSTEM

# **AVIONICS SUBSYSTEM**

**PRECEDING PAGE BLANK NOT FILMED.**

**MCDONNELL DOUGLAS**   
**CORPORATION**

## APPS AVIONICS SUBSYSTEM BLOCK DIAGRAM

The results of our studies show that a nearly autonomous avionics subsystem is the optimum approach for the APPS. The APPS avionics consists of the following primary hardware systems:

Computer/Processor - Evaluates data and monitors APPS and SPA subsystem performance.

Tape Recorder - Stores data for delayed transmission to ground.

Multiplexer Demultiplexer (I/O Mux) - Provides monitors and commands for APPS subsystems and SPA experiments if required.

Signal Conditioner - Conditions APPS subsystem signals to meet I/O Mux, and Caution and Warning input requirements.

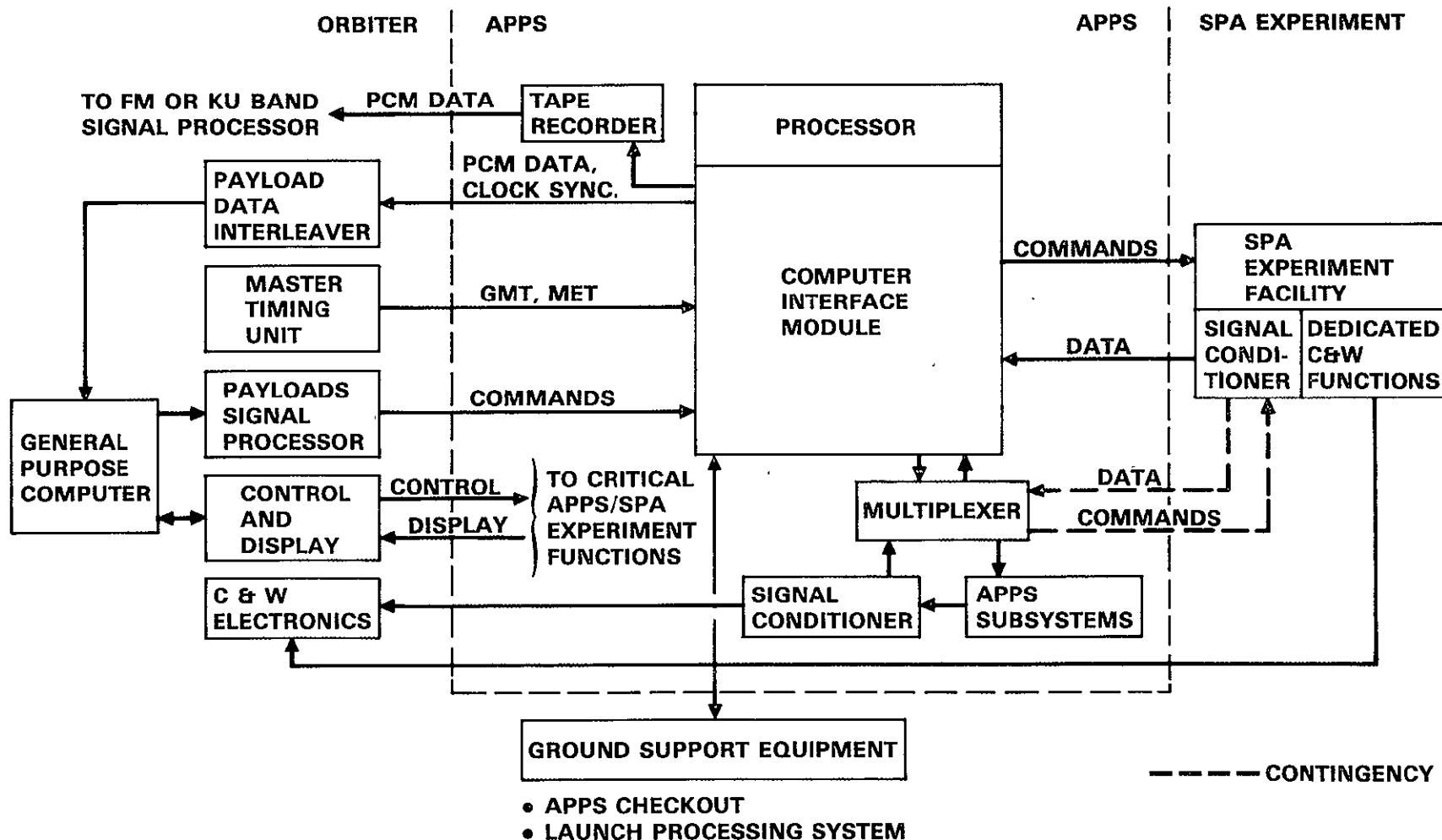
Computer Interface Module - Interfaces Computer/Processor with avionics subsystems and provides the serial digital Input/Output path for SPA experiments.



AUXILIARY  
PAYLOAD  
POWER  
SYSTEM

# APPS AVIONICS SUBSYSTEM BLOCK DIAGRAM

*Our studies show that a nearly autonomous avionics design is optimum*



## AVIONICS FUNCTION

In simple terms, the avionics subsystem is the manager of the APPS. It gathers and stores information from Orbiter, APPS and SPA experiments. The avionics subsystem issues pre-programmed commands and performs management functions during all mission phases. It communicates information to the Orbiter avionics subsystems, to the crew via caution and warning and dedicated displays, and to the ground as commanded. The Phase II study results indicate that the avionics subsystem should not be completely autonomous in its management of the APPS. Certain functions, including the starting of APPS activation, critical or emergency functions, and real-time mission planning, will be performed by the crew.

## AVIONICS FUNCTION

***The avionics subsystem is a key element in the APPS design***

- GATHERS SYSTEMS PERFORMANCE INFORMATION
- ISSUES COMMANDS TO APPS/SPA SYSTEMS
- STORES INFORMATION
- COMMUNICATES INFORMATION:
  - TO ORBITER AVIONICS
  - TO CREW
  - TO GROUND (ON REQUEST)
- MISSION PROGRAMMABLE:
  - PRE-LAUNCH
  - POST LAUNCH FROM GROUND
  - BY CREW
- FUNCTIONS IN ALL MISSION PHASES
  - APPS CHECKOUT
  - INTEGRATED TESTS
  - MISSION

## SELECTED EQUIPMENT

A significant prerequisite for the success of the APPS program is efficient and low cost accommodation of SPA experiments. This manifests itself as an important equipment selection criteria consisting of low program cost in combination with operational flexibility and capability. The majority of the selected APPS avionic equipment consists of space program developed hardware. The signal conditioner, while a new design, is similar to previously qualified equipment flown on Skylab. Development and qualification will be required for the computer interface module. However, since existing technology is planned to be utilized, no new "state-of-the-art" tests should be necessary.

## SELECTED EQUIPMENT

***Flight proven or existing hardware  
has been chosen for the avionics subsystem***

- COMPUTER/PROCESSOR
    - SPACE PROGRAM DEVELOPED HARDWARE  
(LOW COST SYSTEMS OFFICE)
  - TAPE RECORDER
    - SPACE PROGRAM DEVELOPED HARDWARE  
(LOW COST SYSTEMS OFFICE)
  - MULTIPLEXER/DEMULTIPLEXER (I/O MUX)
    - ORBITER MDM DESIGN
  - SIGNAL CONDITIONER
    - NEW DESIGN SIMILAR TO PREVIOUS SPACE APPLICATIONS  
(SKYLAB)
- COMPUTER INTERFACE MODULE
- NEW DESIGN REQUIRING DEVELOPMENT AND QUALIFICATION

## APPS AVIONICS SUBSYSTEM INTERFACES

The avionics subsystem interfaces all other APPS subsystems and the Orbiter and SPA experiments. No avionics interfaces with the Spacelab were identified during the study.

The APPS-Orbiter avionics interfaces use the standard payload interface connections and interface panels. No changes to this interface will be required for different complements of SPA experiments.

The primary APPS-SPA experiment interfaces are via serial digital input/output paths (minimum of 4). Also provided will be a limited number of discrete and analog monitors for use by the SPA experiments.

Mission to mission SPA experiment complement changes will only require interface cabling and software updates.

# APPS AVIONICS SUBSYSTEM INTERFACES

***Standardized interfaces minimize  
impact on external subsystems***

## **APPS TO ORBITER**

- DATA MANAGEMENT
  - PCM DATA FROM APPS TAPE RECORDER TO FM OR KV BAND SIGNAL PROCESSOR
  - PCM DATA, CLOCK, SYNC FROM COMPUTER INTERFACE  
MODULE (CIM) TO PAYLOAD DATA INTERLEAVER
  - TIMING SIGNALS (MET, GMT) FROM ORBITER MASTER TIMING UNIT TO CIM
  - COMMANDS FROM ORBITER PAYLOAD SIGNAL PROCESSOR TO CIM
- CONTROL AND DISPLAY
  - CRITICAL CONTROL FUNCTIONS
- CAUTION AND WARNING
  - C&W FUNCTIONS TO ORBITER C&W ELECTRONICS

## **APPS TO SPA EXPERIMENTS**

- SPA EXPERIMENT CONTROL
  - APPS PROVIDES EXECUTIVE CONTROL
- DATA MANAGEMENT
  - APPS RECORDS DATA, ACCEPTS AND DIGITIZES 64 ANALOG INPUTS,  
ACCEPTS (& OUTPUTS) 48 DISCRETES
- VIDEO
  - APPS PROVIDES CABLE (ONLY) FOR EXPERIMENT TV SYSTEM

## APPS SOFTWARE

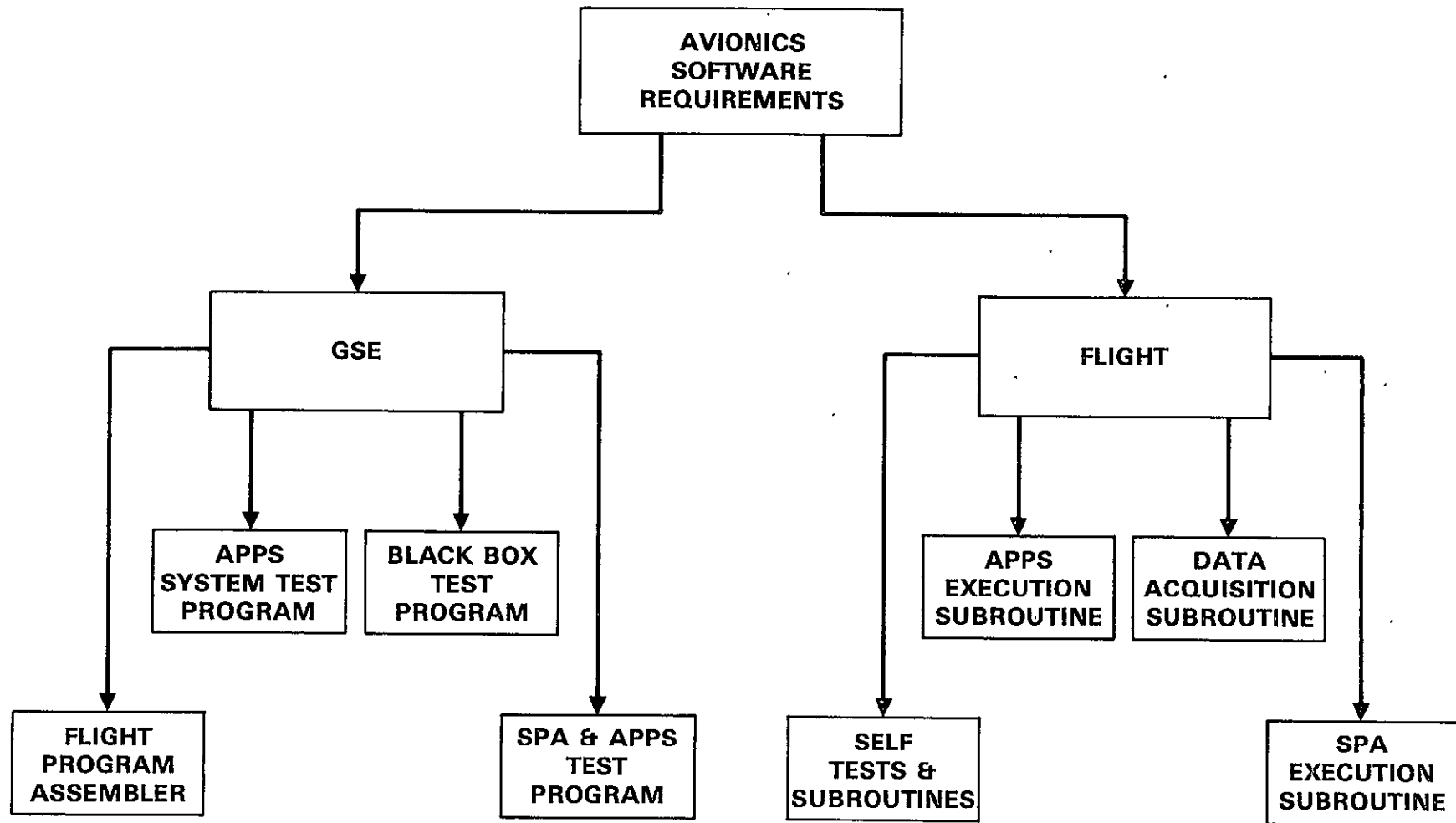
The developed APPS avionics software requirements recognize the importance and interrelationships of both ground checkout and the management of flight operations. Software requirements are categorized as GSE or flight. GSE software requirements include the flight program assembler and the test programs required for verification of the APPS system and subsystems, as well as integrated testing of the APPS and SPA experiments. Flight software requirements consist of subsystem self test, data acquisition and the control subroutines for APPS and SPA experiments.



AUXILIARY  
PAYLOAD  
POWER  
SYSTEM

# SOFTWARE

***Efficiently structured software  
minimizes hardware requirements***



MCDONNELL DOUGLAS  
CORPORATION

### APPS AVIONICS SUBSYSTEM OPERATIONAL REQUIREMENTS

The avionics subsystem has been designed for maximum autonomy from the Orbiter avionics or ground control. Prior to APPS activation, only caution and warning monitoring is required from the Orbiter. At activation, a start command is required from the Orbiter Payload Specialist Panel which activates the APPS avionics subsystem, and in turn activates other APPS subsystems. Periodically, tape recorder stored data is downlinked via the Orbiter. During downlink periods, APPS real time data is downlinked by the Orbiter to provide continuous data coverage. GMT and MET timing signals are provided to the APPS computer from the Orbiter Master Timing Unit. Ground commands are received by the Orbiter and processed for transmission to the APPS computer and subsequent execution. During the reentry and recovery period, the Orbiter monitors critical APPS and SPA experiment caution and warning parameters. Reduction of APPS and SPA experiment telemetered data is required by the ground based equipment for post-flight analysis.

## APPS AVIONICS SUBSYSTEM OPERATIONAL REQUIREMENTS

*Primary requirement is for nearly autonomous mission operations with capability for efficient ground turnaround*

### MISSION

- EXECUTIVE FLIGHT PROGRAM (MODIFY AS REQUIRED)
- EXECUTIVE CONTROL OF SPA EXPERIMENTS
- DATA MANAGEMENT

### GROUND TURNAROUND

- POST-FLIGHT SYSTEMS VERIFICATION
- POST-MAINTENANCE CHECKOUT
- EXPERIMENT INTEGRATION
- INTEGRATED SYSTEMS TESTS
  - SIMULATED INTERFACES
- ORBITER INTEGRATION
- PRELAUNCH
- LAUNCH

THIS PAGE INTENTIONALLY LEFT BLANK

AUXILIARY  
PAYLOAD  
POWER  
SYSTEM

## ELECTRICAL POWER SUBSYSTEM

~~PRECEDING PAGE BLANK NOT FILMED.~~

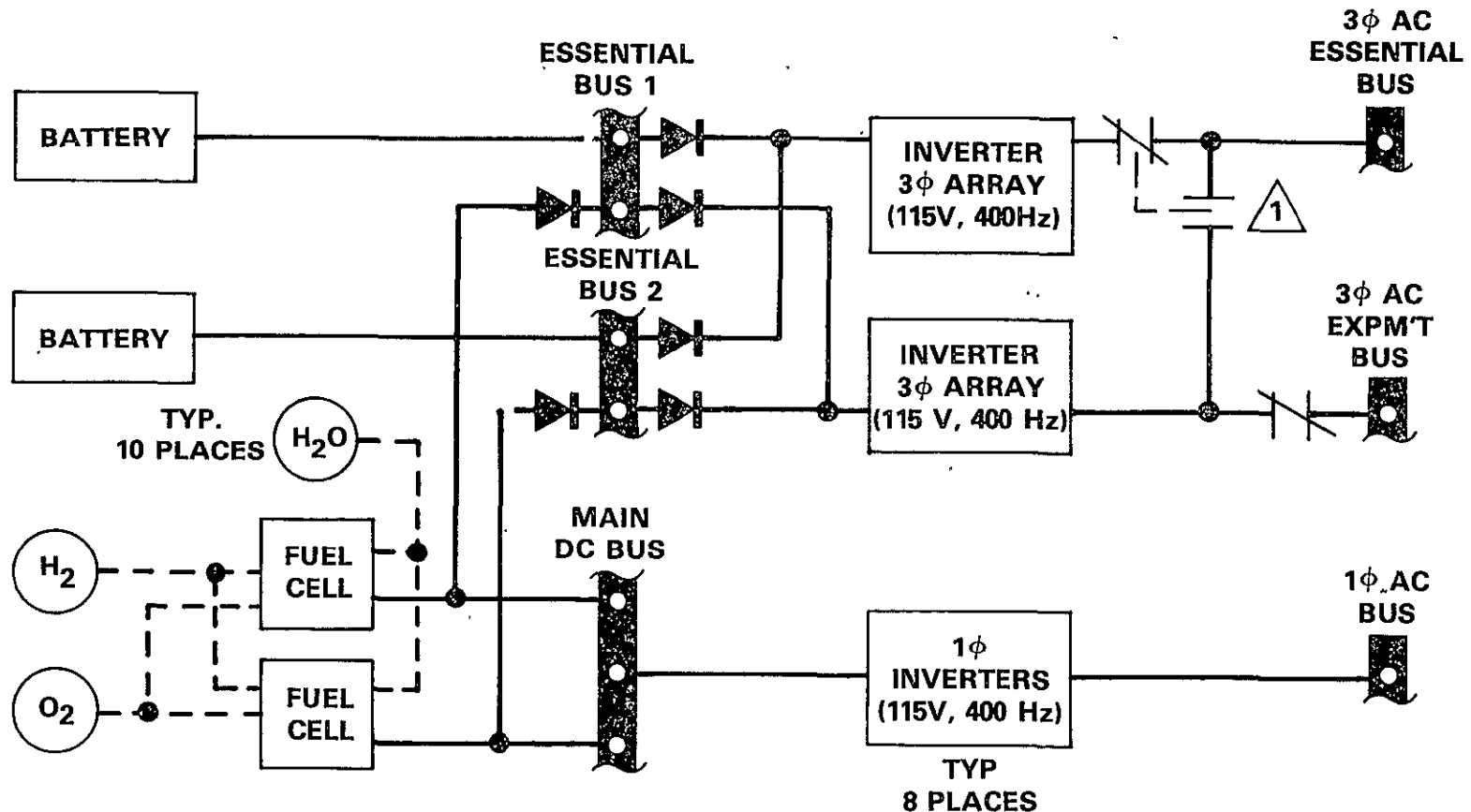
MCDONNELL DOUGLAS  
CORPORATION

### APPS EPS SIMPLIFIED BLOCK DIAGRAM

Developed hardware has been used to the maximum practical extent in the APPS Electrical Power Subsystem. During prelaunch operations, essential APPS equipment is powered from the Shuttle GSE source through the APPS/Orbiter interface. At launch, the APPS/Orbiter interface is opened and the secondary silver-zinc batteries power the essential buses. Batteries are recharged on orbit over a period of approximately 24 hours, and used during the reentry and recovery period after fuel cell shutdown. Two Shuttle type fuel cells are the prime power source. Reactants are stored in Shuttle type reactant tanks, and fuel cell product water is stored on board in 10 Shuttle type water tanks. Three phase AC power is required for fuel cell auxiliary equipment, radiator deployment and retraction motors, and coolant pumps. Total power requirements exceed the capability of one three phase Shuttle type inverter array. Therefore, two arrays are provided, with the second powering the SPA experiment coolant loop pump only. The 3 phase motors can operate with reduced performance on 2 phases. Control logic is provided to switch over the 3 phase array powering the experiment loop coolant pump to the essential APPS 3 phase bus if 2 phases of the essential 3 phase bus fail. In this event, thermal control of experiments is terminated. Single phase AC power is provided for SPA experiments by 8 Shuttle type inverters in parallel.

# APPS EPS SIMPLIFIED BLOCK DIAGRAM

*Subsystem design emphasizes reliability, interface compatibility, and minimum development risk*



NOTE: **1** SWITCHOVER OCCURS IF TWO PHASES OF 3 $\phi$  AC ESSENTIAL BUS FAIL. IN THIS EVENT, EXPERIMENTS THERMAL CONTROL IS TERMINATED.

## ELECTRICAL POWER SUBSYSTEM SUMMARY

Shuttle type hardware is used extensively in EPS design to reduce development costs. The prime power source is two fuel cells connected in parallel. A sustained power capability of 14 kW, 7 kW per fuel cell, is consistent with Shuttle usage. Similarly, the 24 kW peak capability is based on Shuttle usage. The fuel cell manufacturer believes that sustained operation at 12 kW/fuel cell is acceptable; however, verification would entail additional qualification testing. For the worst thermal case, the APPS radiator heat rejection capability permits sustained operation at 16 kW approximately. Reactants are stored in two each hydrogen and oxygen tanks and provide a stored energy of 1932 kWh. The secondary silver-zinc batteries provide energy to essential loads when the fuel cells are dormant, and are recharged on orbit from the fuel cell source. DC/AC inverters are provided to satisfy three phase and single phase AC loads. Prelaunch power is supplied by Shuttle GSE supplies through the APPS/Orbiter interface. All feeders interconnecting the APPS power sources with other modules or with using equipment are protected with fuses to provide fault isolation and source protection.



## ELECTRICAL POWER SUBSYSTEM SUMMARY

***EPS design features extensive utilization of developed hardware, near autonomous operation, and high power/energy capability***

- PRIME POWER SOURCE IS TWO SHUTTLE FUEL CELLS CONNECTED IN PARALLEL
- SECONDARY SILVER-ZINC BATTERIES AND CHARGERS PROVIDE ENERGY WHEN FUEL CELLS ARE DORMANT
- CONDITIONED AC POWER SUPPLIED BY SHUTTLE TYPE INVERTERS
- FUEL CELL PRODUCT WATER STORED IN SHUTTLE TYPE WATER TANKS
- FUEL CELL REACTANTS STORED IN SHUTTLE TYPE REACTANT TANKS
- DESIGN PROVIDES AUTONOMOUS APPS OPERATION FROM LAUNCH THROUGH RECOVERY
- POWER CAPABILITY 14 KW SUSTAINED, 24 KW PEAK FOR 15 MINUTES AT 3 HOUR INTERVALS
- TOTAL ENERGY CAPABILITY 1932 KWH
- ON PAD POWER SUPPLIED BY SHUTTLE GROUND POWER SUPPLIES
- ALL WIRING FROM DISTRIBUTION BUSES IS PROTECTED

## ELECTRICAL POWER SUBSYSTEM CONCEPT SELECTION RATIONALE

Seven alternate EPS concepts were evaluated for the APPS application as follows:

(1) Shuttle Fuel Cell, (2) Tug Lightweight Fuel Cell, (3) Optimized Lightweight Fuel Cell, (4) Brayton Cycle/Radioisotope Heat Source, (5) Brayton Cycle/Reactor Heat Source, (6) Solar Array/Secondary Battery, and (7) Auxiliary Power Unit. The best overall concept from the standpoint of weight, volume, cost, and development risk is the Shuttle Fuel Cell concept. APPS missions with a lower power or energy requirement than the baseline can be readily accommodated by the removal of one fuel cell, or one set of reactant tanks, or both. This enhances the ability of the APPS to fly on missions of opportunity.

## **ELECTRICAL POWER SUBSYSTEM CONCEPT SELECTION RATIONALE**

***Shuttle fuel cell concept is best overall power subsystem for APPS application***

- **MINIMAL DEVELOPMENT REQUIRED**
- **WEIGHT AND VOLUME ARE LOW COMPARED TO ALTERNATE CONCEPTS**
- **LOW COST**
- **MAXIMUM COMMONALITY WITH SHUTTLE HARDWARE**
- **COMPATIBLE WITH INTERFACE REQUIREMENTS**
- **MODULARITY IN POWER AND ENERGY CAPABILITIES**

## APPS ELECTRICAL POWER SUBSYSTEM INTERFACES

EPS interfaces with the Orbiter, SPA Experiments, and Spacelab are identified on the facing page. Prelaunch power requirements identified thus far are minimal, 20 watts for APPS Caution and Warning and 150 watts for Electrophoresis experiment thermal control. The APPS requires no power from external sources after launch. A hardline command to the APPS is required at T-0 approximately to open the APPS/Orbiter interface, turn on the APPS batteries, and isolate the APPS main DC bus and essential buses. Reactant servicing is completed prior to close out at T-4 hours. Four fill, four vent, and two drain lines are required. The APPS provides a total of 10 kW of 28 VDC power on a sustained basis to SPA experiments, a portion of which can be supplied as conditioned single phase AC power. Average AC power available to the interface is 5280 VA. Mix of DC and AC power is at the user's option within the capability of 10 kW sustained, 12 kW peak total DC power. For purposes of determination of total DC load, a DC to AC conversion efficiency of 80 percent is assumed. An interface with the Spacelab is also provided with capabilities of 4 kW sustained, 6 kW peak DC power. Total energy available to payloads after allowing for APPS housekeeping requirements is approximately 1300 kWh.

## APPS ELECTRICAL POWER SUBSYSTEM INTERFACES

***APPS electrical power system  
interfaces with orbiter, SPA experiments, and Spacelab***

### APPS TO ORBITER

- POWER TRANSFER
  - 1 KW AVERAGE POWER TO APPS PRELAUNCH
  - NO POWER TRANSFER AFTER LAUNCH, EXCEPT FOR CONTINGENCIES
- HARDLINE COMMANDS
  - HARDLINE COMMAND CAPABILITY AT PAYLOAD SPECIALIST PANEL (STARTUP, SHUTDOWN, & SAFETY FUNCTIONS ONLY)
  - HARDLINE COMMAND AT T-O APPROXIMATELY TO OPEN CIRCUIT APPS/ORBITER INTERFACE AND TURN ON APPS BATTERIES
- EMERGENCY WATER DUMP
  - INTERFACES WITH ORBITER DUMPLINE
- FUEL CELL PURGE
  - INTERFACES WITH ORBITER FUEL CELL H<sub>2</sub> & O<sub>2</sub> PURGE LINES
- REACTANT SERVICING
  - SEPARATE FILL, VENT, AND DRAIN LINES ROUTED THRU PAYLOAD PRELAUNCH SERVICE PANEL TO ORBITER CRYO SERVICING PANEL (10 LINES)

### APPS TO SPA EXPERIMENTS

- POWER TRANSFER
  - 10 KW SUSTAINED, 12 KW PEAK FOR 15 MINUTES AT 3 HOUR INTERVALS
  - UP TO 5280 VA AVERAGE, 115 VAC, 1 $\phi$
  - MIX OF DC & AC POWER AT USER'S OPTION CONSISTENT WITH MAXIMUM CAPABILITY OF 10 KW DC AVERAGE

### APPS TO SPACELAB

- POWER TRANSFER
  - 4 KW SUSTAINED, 6 KW PEAK FOR 15 MINUTES AT 3 HOUR INTERVALS

## APPS ELECTRICAL POWER SUBSYSTEM OPERATIONAL REQUIREMENTS

The APPS electrical power subsystem has been designed to minimize the impact on Shuttle operations. During prelaunch operations on the launch pad, APPS power requirements are satisfied by Shuttle ground power supplies through the APPS/Orbiter interface to eliminate any drain on the APPS batteries. Fuel cell reactant servicing is accomplished through the Orbiter cryo servicing panel. At T-0 approximately, a command is required to turn on the APPS batteries, open the tie between the APPS main DC bus and the essential buses, and open the APPS/Orbiter interface. After achieving orbit, a start command is required from the Orbiter Payload Specialist Panel which activates the APPS Avionic Subsystem and, in turn, activates the EPS. Operation of the EPS is then completely autonomous, until shutdown preparatory to entry and recovery. A shutdown command is required to completely power down the APPS. Post flight operations include deservicing of the water and reactant tanks, and turn off of the APPS batteries.

## APPS ELECTRICAL POWER SUBSYSTEM OPERATIONAL REQUIREMENTS

***EPS operation is autonomous except for startup and shutdown***

- **PRELAUNCH**

- APPS POWER REQUIREMENTS ARE SATISFIED BY SHUTTLE GROUND POWER SUPPLIES THROUGH APPS/ ORBITER INTERFACE
- AT T-O APPROXIMATELY, APPS/ORBITER INTERFACE IS OPENED, APPS BATTERIES TURNED ON, AND MAIN TO ESSENTIAL BUS TIES ARE OPENED
- FUEL CELL REACTANT SERVICING THROUGH ORBITER CRYO SERVICING PANEL

- **MISSION**

- STARTUP & SHUTDOWN COMMANDS ARE REQUIRED FROM PAYLOAD SPECIALIST PANEL

- **POST-FLIGHT**

- WATER TANK DESERVICE
- FUEL CELL REACTANT TANK DESERVICE
- APPS BATTERIES OFF

THIS PAGE INTENTIONALLY LEFT BLANK



AUXILIARY  
PAYLOAD  
POWER  
SYSTEM

# THERMAL CONTROL SUBSYSTEM

PRECEDING PAGE BLANK NOT FILMED.



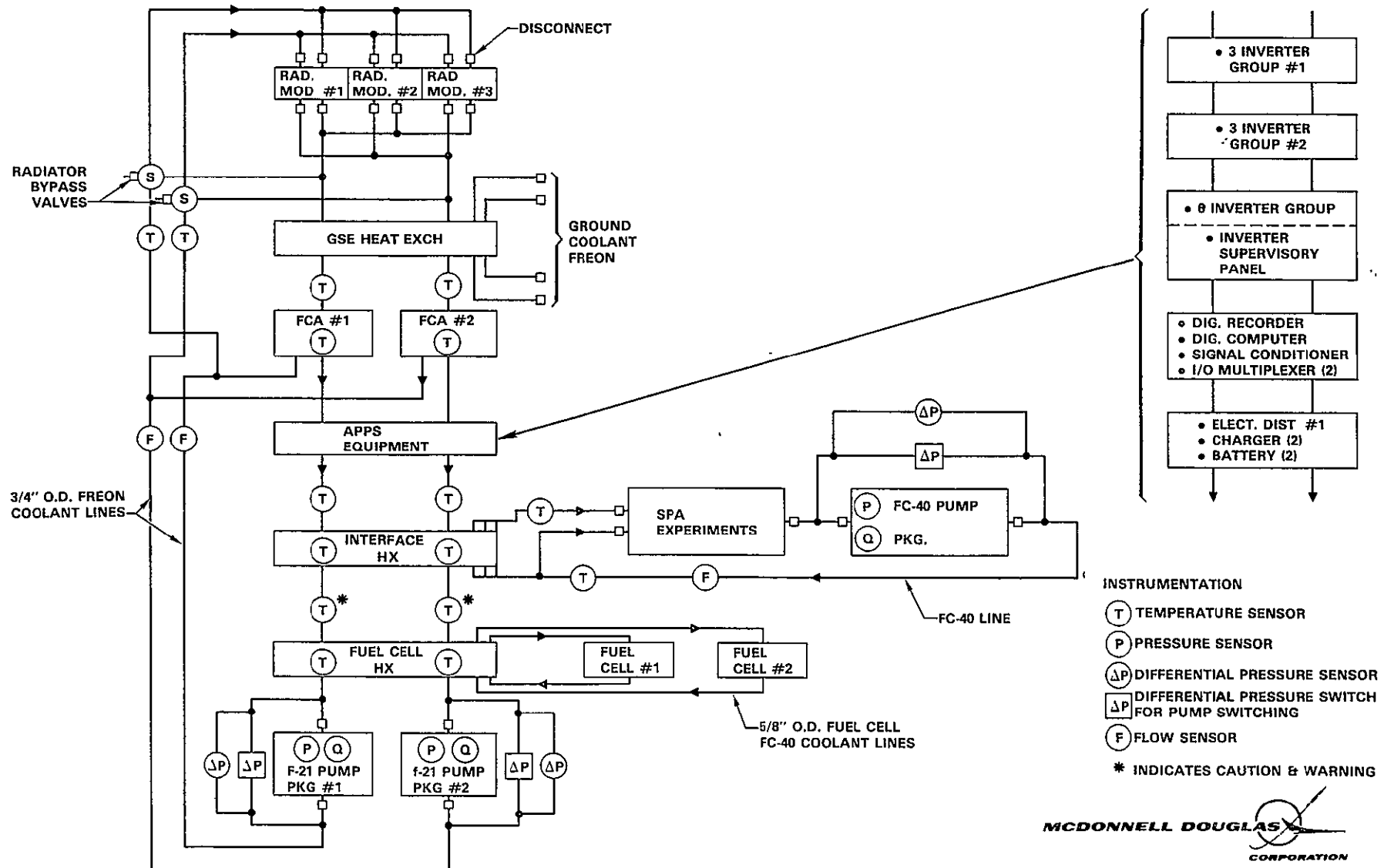
### APPS COOLANT LOOP SCHEMATIC

The APPS TCS coolant loop arrangement and equipment are shown. The F-21 equipment loop contains the APPS housekeeping electrical and avionics coldplated components, fuel cell heat exchanger, GSE heat exchanger, space radiator, F-21 pump packages, and interface heat exchanger. The FC-40 experiments loop rejects its heat to the equipment loop via the interface heat exchanger. The schematic also shows the basic analog instrumentation planned for the TCS.

AUXILIARY  
PAYLOAD  
POWER  
SYSTEM

# APPS COOLANT LOOP SCHEMATIC

**TCS configuration based upon satisfying equipment cooling needs**

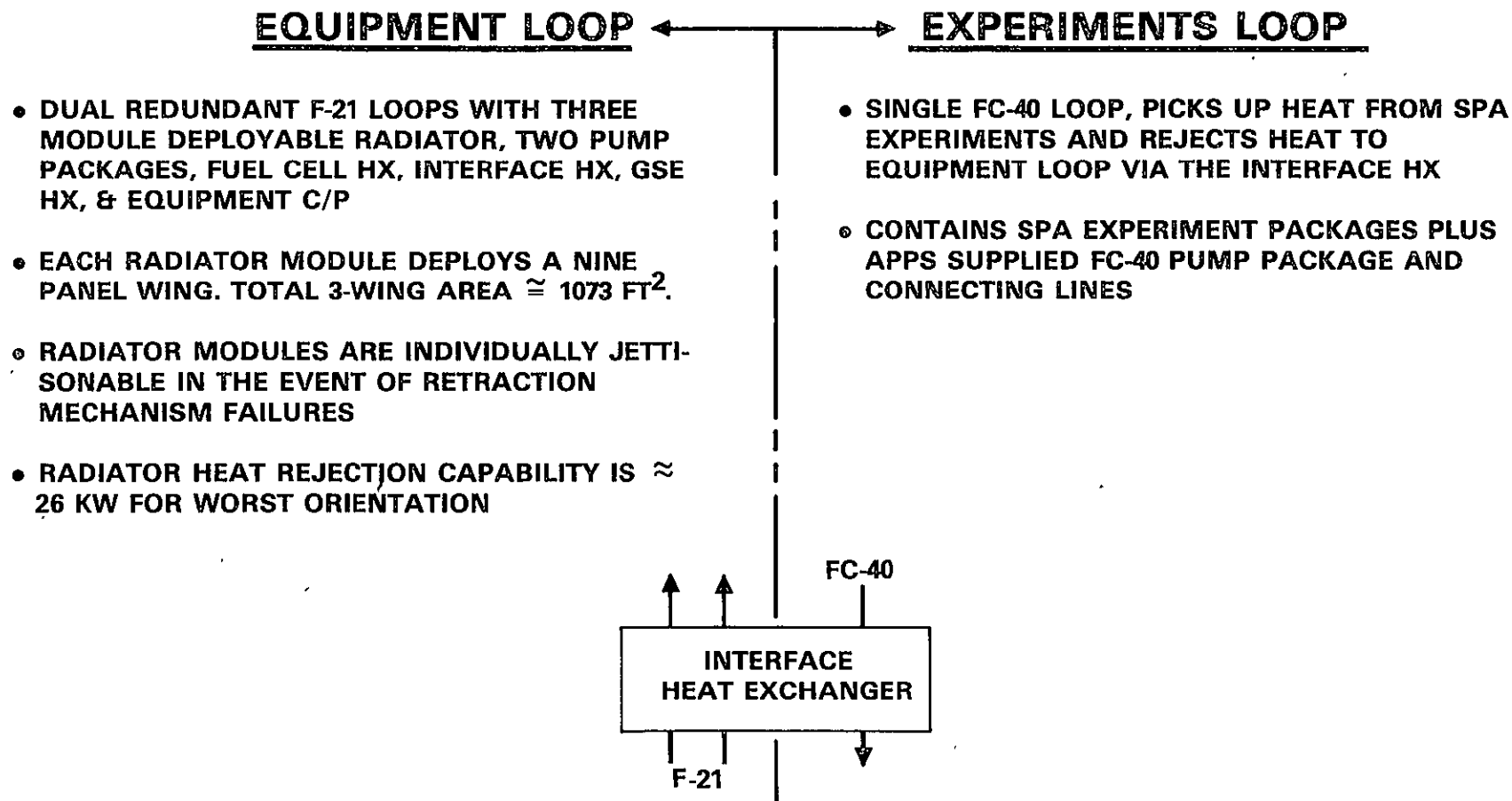


### APPS TCS.PRINCIPAL FEATURES

The principal features of the APPS equipment and experiments coolant loops are listed. The active cooling provisions are supplemented by use of special thermal control coatings and/or insulation on components and structure as needed. Heaters are used to prevent freezing of fuel cell water product storage bottles for cold mode conditions.

## APPS TCS PRINCIPAL FEATURES

*The APPS TCS is designed around the SPA experiments*



### APPS TCS RATIONALE FOR SELECTION

Emphasis was placed on selecting TCS hardware that was available from the Shuttle to minimize development requirements. Hardware and technology from other spacecraft programs are used when not available from Shuttle. Some development costs will be incurred to verify the radiator panel swivel design and the FC-40 coolant pump design.

## APPS TCS RATIONALE FOR SELECTION

***The APPS TCS design uses "state-of-the-art" components and design technology to assure minimum development time and cost***

- THE EQUIPMENT COOLANT LOOP CONSISTS PRIMARILY OF SHUTTLE DERIVED COMPONENTS
  - F-21 COOLANT PUMP PACKAGES (2)
  - FUEL CELL HX
  - INTERFACE HX (1) — SAME AS FUEL CELL HX
  - GSE HX (1)
  - RADIATOR FLOW CONTROL ASSEMBLIES (2)
  - RADIATOR BYPASS VALVES
  - RADIATOR PANEL DESIGN & COATING
- THE RADIATOR DEPLOYMENT/RETRACTION MECHANISM DESIGN IS BASED ON THE NASA-MSFC SKYLAB SOLAR ARRAY DESIGN
  - PANEL TO PANEL INTERCONNECTING SWIVELS BASED ON NASA-JSC/VOUGHT DEVELOPMENT WORK
  - MODULE JETTISON DEVICES BASED ON DESIGNS USED FOR SCOUT & AMU
- THE EXPERIMENTS LOOP FC-40 PUMP IS SIMILAR TO THE SHUTTLE FUEL CELL COOLANT PUMP AND F-15 AIRPLANE COOLANT PUMP DESIGN (TENTATIVELY SAME VENDOR)

### APPS TCS INTERFACES

The present APPS TCS interfaces are with the Shuttle and the APPS mounted SPA experiments. An interface may also be extended to the Spacelab if SPA experiments in the Spacelab require cooling by the APPS TCS. Presently no requirement exists to provide cooling to the Spacelab. Heat exchange between the APPS and companion payload modules in the Shuttle payload bay will be minimized. The APPS to SPA interface definitions include results derived from the APPS/Payload contractor thermal interface meeting at MSFC on 9-10 June 1976.



## APPS TCS INTERFACES

***The APPS TCS interfaces primarily with the SPA experiments***

### APPS TO SHUTTLE

- HEAT EXCHANGE BETWEEN THE APPS AND SHUTTLE SHALL BE MINIMIZED
  - 10% MAXIMUM VIEWFACTOR FROM APPS RADIATOR TO SHUTTLE RADIATOR
  - MINIMIZE HEAT TRANSFER FROM APPS HEAT PRODUCING EQUIPMENT THROUGH USE OF APPROPRIATE INSULATION & COATINGS

### APPS TO SPA EXPERIMENTS

- MAXIMUM EXPERIMENTS LOOP HEAT LOAD IS 11 KW BASED ON 10 KW SPA EXPERIMENTS HEAT LOAD AND 1 KW FC-40 PUMP HEAT INPUT
- FC-40 PUMP FLOW RATE = 7900 LB/HR AT 50 PSI PUMP PRESSURE RISE
  - SPA EXPERIMENTS  $\Delta P$  = 36 PSI MAXIMUM BETWEEN CONNECTORS
  - MAXIMUM FC-40 PRESSURE LEVEL = 75 PSI
- INTERFACE HX FC-40 OUTLET TEMPERATURE OF 30 TO 120°F
- APPS PROVIDES THERMAL BARRIER ISOLATING SPA EXPERIMENTS FROM EXTERNAL ENVIRONMENT

### APPS TCS OPERATIONAL REQUIREMENTS

The various operational requirements of the APPS TCS are defined. These requirements were established during the APPS Phase A and Phase II studies.

# APPS TCS OPERATIONAL REQUIREMENTS

(Sheet 1 of 2)

## *The TCS satisfies a variety of operational requirements*

- GROUND — APPS WILL BE COMPATIBLE WITH THE SHUTTLE PAYLOAD BAY ENVIRONMENT PROVIDED PER JSC 07700 VOL. XIV.
  - APPS GSE HEAT EXCHANGER WILL ONLY BE USED FOR PRE-PAD EQUIPMENT OPERATIONS TESTS
    - NOT REQUIRED FOR ON-PAD PRELAUNCH CHECKOUT OR POST-LANDING COOLDOWN
- MISSION — RADIATOR HEAT LOAD (1)
  - SUSTAINED 22 KW MAX
  - PEAK 38 KW (15 MIN. PEAK AT 3 HR INTERVALS)
  - EQUIPMENT LOOP RADIATOR FCA COOLANT OUTLET TEMPERATURE 100°F MAX  
36°F MIN
  - EQUIPMENT LOOP COLDPLATE SURFACE TEMPERATURE 125°F MAX  
30°F MIN
  - INTERFACE HEAT EXCHANGER/EXPERIMENTS LOOP COOLANT OUTLET TEMPERATURE 120°F MAX  
30°F MIN
  - FUEL CELL FC-40 COOLANT OUTLET FROM FUEL CELL HEAT EXCHANGER 140° F MAX

THIS PAGE INTENTIONALLY LEFT BLANK

# APPS TCS OPERATIONAL REQUIREMENTS

(Sheet 2 of 2)

## • MISSION (CONTINUED)

— EXPERIMENTS LOOP HEAT LOAD (2)	11 KW MAX SUSTAINED
— ORBIT THERMAL DESIGN ENVIRONMENT	
• SOLAR HEAT FLUX	1394 WATTS/M <sup>2</sup> (442 BTU/HR-FT <sup>2</sup> )
• EARTH ALBEDO	0.3
• EARTH IR HEAT FLUX	243 WATTS/M <sup>2</sup> (77 BTU/HR-FT <sup>2</sup> )
— DESIGN ORBIT (CIRCULAR)	
• ALTITUDE	185 KM(100NM) TO 926 KM (500 M)
• BETA ANGLE	0 ± 90°
— PAYLOAD BAY THERMAL DESIGN ENVIRONMENT	REF JSC 07700 VOL XIV, SSS PAYLOAD ACCOMMODATIONS, REV. C, PARA. 4.2.2.7

## NOTES.

(1) BASED ON 63% FUEL CELL EFFICIENCY

(2) CONSISTS OF 10 KW FOR EXPERIMENTS, 1 KW FOR PUMP POWER

~~PRECEDING PAGE BLANK NOT FILMED.~~

THIS PAGE INTENTIONALLY LEFT BLANK

AUXILIARY  
PAYLOAD  
POWER  
SYSTEM

# STRUCTURAL/MECHANICAL SUBSYSTEM

~~PRECEDING PAGE BLANK NOT FILMED.~~



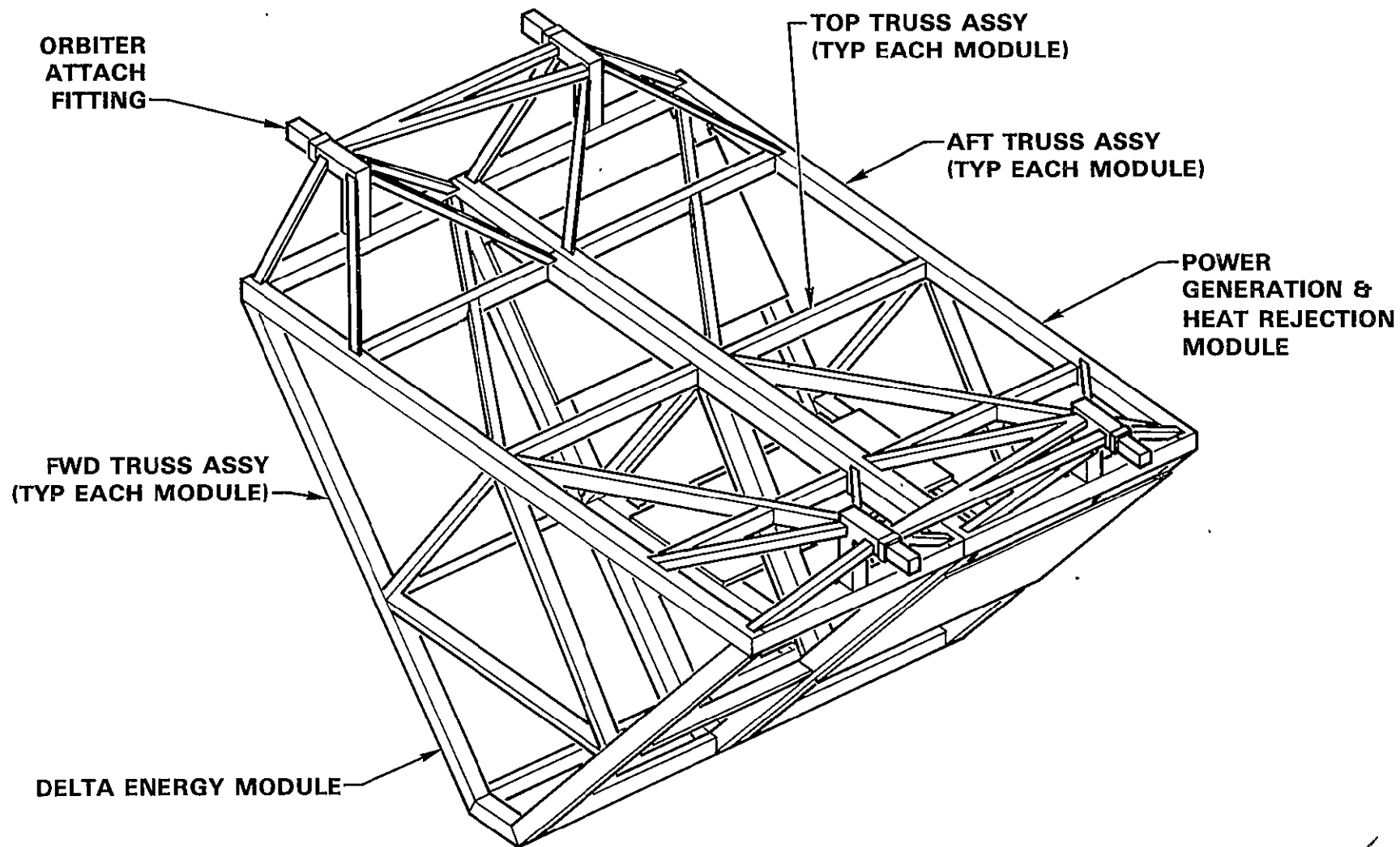
## STRUCTURAL SUBSYSTEM

The design goals established for the structural subsystem were a modular configuration consisting of a Power Generation and Heat Rejection Module and a Delta Energy Module capable of supporting the other APPS subsystems and with a module experiment payload accommodation capability of 200 ft<sup>3</sup> (1300 lbm) and 430 ft<sup>3</sup> (2700 lbm). Limiting APPS dimensions of a dynamic envelope 15.0 ft in diameter, except for mounting attachments and the deployed radiator, and an overall length of 9.0 ft were established. The structural subsystem shown in this chart met the established design goals.



AUXILIARY  
PAYLOAD  
POWER  
SYSTEM

## STRUCTURAL SUBSYSTEM



## STRUCTURAL SUBSYSTEM - RATIONALE FOR SELECTION

The various alternate structural subsystem concepts evaluated led to the selection of a custom structure modular open truss configuration. A custom structure was selected to provide the capability of supporting the remaining APPS subsystems and the design reference SPA experiment complement. The modular configuration provides the mission flexibility of capturing more missions of opportunity with a shorter length when reduced electrical energy capability and experiment payload accommodation are acceptable. An open truss structure was shown to be lighter in weight and stiffer than the other concepts evaluated. A truss constructed of square and rectangular weldable aluminum alloy was found to be most cost effective from a producibility standpoint. Use of redundant supports at the APPS/Orbiter mechanical interface, rather than statically determinate supports, reduced the structural weight and deflections.

## **STRUCTURAL SUBSYSTEM — RATIONALE FOR SELECTION**

**CUSTOM STRUCTURE** — PROVIDES REQUIRED PAYLOAD CAPABILITY

**MODULAR CONFIGURATION** — CAPTURES MAXIMUM NUMBER OF MISSIONS OF OPPORTUNITY

**OPEN TRUSS** — LIGHT WEIGHT AND STIFF

**SQUARE & RECTANGULAR TUBING** — REDUCES COST OF FITTING TUBES PRIOR TO WELDING AND PROVIDES FLAT SURFACE FOR EQUIPMENT ATTACHMENT

**WELDABLE ALLOYS** — ELIMINATES MACHINED FITTINGS AND MECHANICAL ATTACHMENTS

**REDUNDANT SUPPORTS** — DECREASES DEFLECTIONS AND WEIGHT

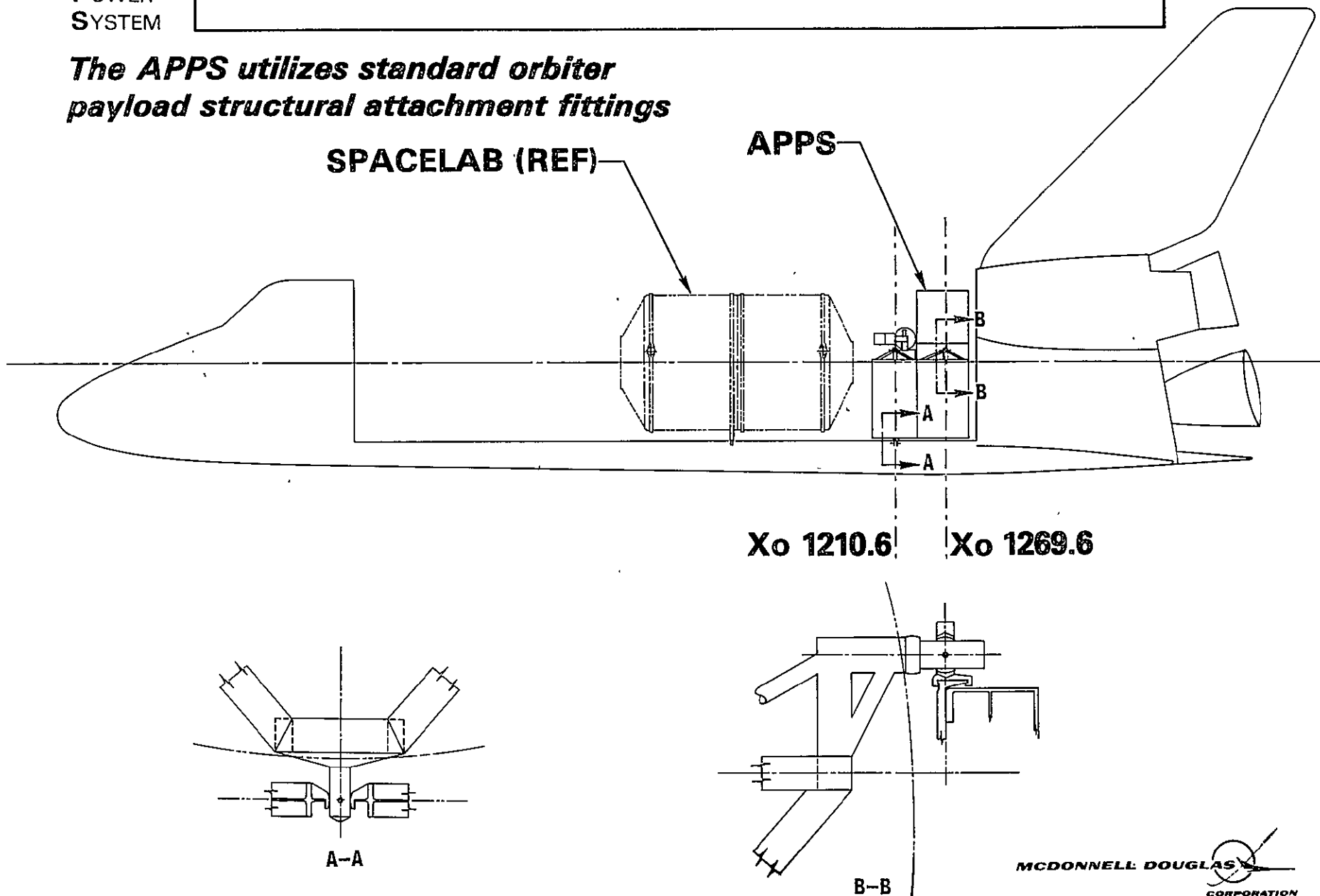
## APPS/ORBITER MECHANICAL INTERFACE

The APPS interface attachment is a four point statically indeterminate installation where two opposite primary longeron fittings react both X and Z loads and two opposite longeron stabilization fittings react only Z loads. A single keel fitting is used to react Y loads. The APPS to Orbiter longeron interface is a standard interface trunnion on the APPS mating with a bearing in a journal on the Orbiter longeron. A cantilevered member on the APPS interfaces with a slot in the Orbiter keel bridge fitting to resist lateral loads while providing freedom of motion along the X and Z axes.

AUXILIARY  
PAYLOAD  
POWER  
SYSTEM

## APPS/ORBITER MECHANICAL INTERFACE

*The APPS utilizes standard orbiter  
payload structural attachment fittings*

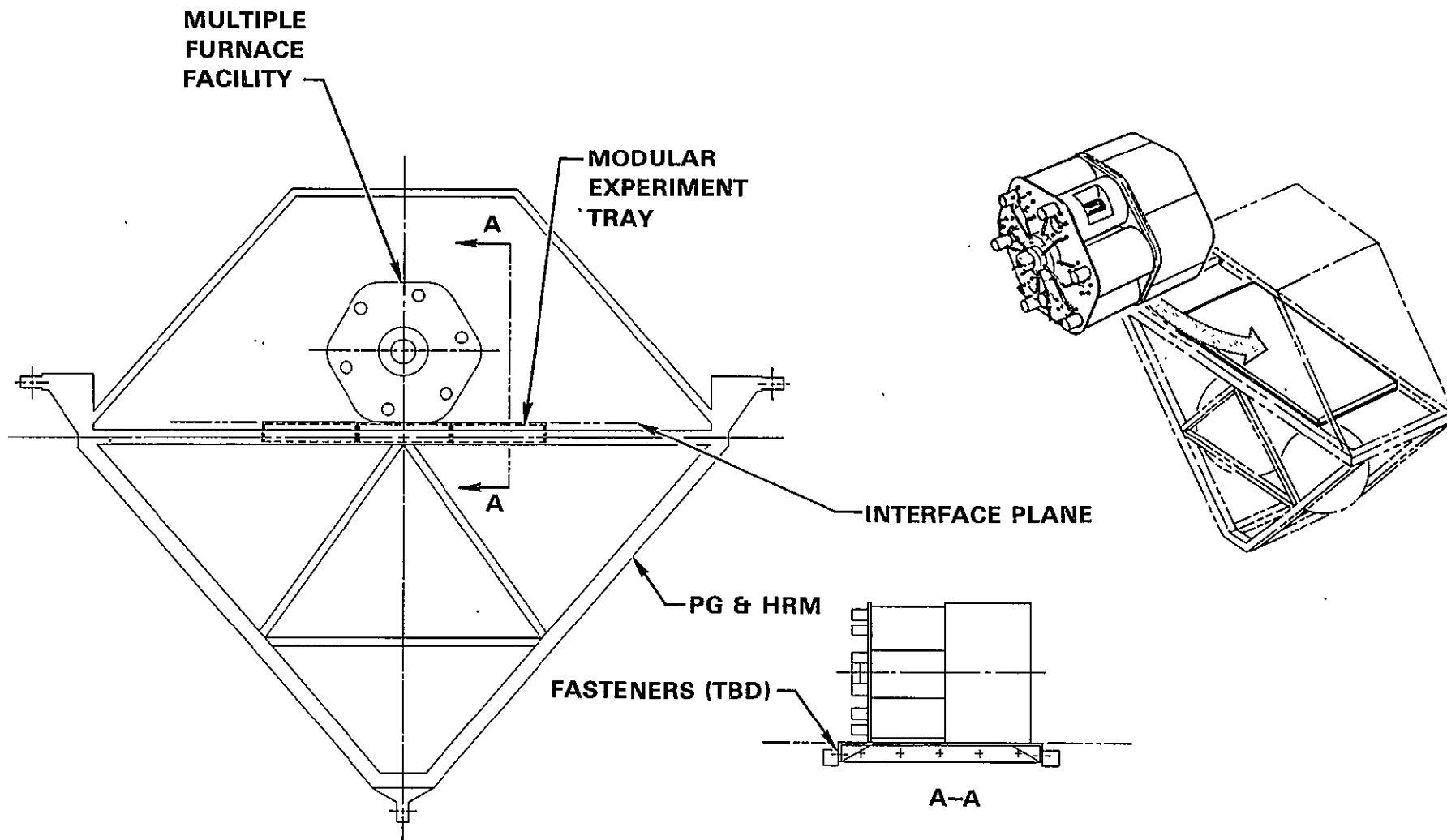


### APPS/SPA EXPERIMENT MECHANICAL INTERFACE

The APPS structural subsystem provides a series of removable and interchangeable experiment trays for SPA experiment equipment. These trays are capable of supporting the integrated SPA experiment equipment items and the associated electrical wiring and cooling fluid lines up to their respective interfaces with the APPS, prior to installation of the experiment tray in the APPS. This concept is shown on the opposite chart for a typical SPA experiment. The mechanical interface is established between the experiment equipment and the tray since the structural subsystem is configured to accommodate up to five sections of experiment trays.

AUXILIARY  
PAYLOAD  
POWER  
SYSTEM

# APPS/SPA EXPERIMENT MECHANICAL INTERFACE



MCDONNELL DOUGLAS  
CORPORATION

## STRUCTURAL SUBSYSTEM DESIGN CRITERIA AND LOADS

The APPS structural subsystem design criteria and loads are summarized on the opposite page. The structure is sized to support the payload during critical load conditions occurring during Shuttle liftoff, landing and crash. No structural qualification testing will be conducted. A factor of safety of 2.0 is used in analysis and sizing of the structure. No detrimental structural deflections are allowed at limit load and no failure is permitted at ultimate load. All structural deflections at limit loads are maintained to within the 180 inch diameter allotted space.



## STRUCTURAL SUBSYSTEM DESIGN CRITERIA AND LOADS

*Design margins chosen to minimize development costs*

- **CRITICAL LOAD CONDITIONS: SHUTTLE LIFTOFF, LANDING, CRASH**
- **NO MAJOR STRUCTURAL TESTS REQUIRED**
- **FACTOR OF SAFETY = 2.0**
- **NO DETRIMENTAL DEFLECTION AT LIMIT LOAD**
- **NO FAILURE AT ULTIMATE LOAD**
- **DEFLECTION NOT TO EXCEED 180 INCH DIAMETER ENVELOPE**

## APPS GENERAL ARRANGEMENT

The APPS dual module configuration shown on the facing page provides the flexibility necessary to capture missions of opportunity as a companion payload on Shuttle flights. The power generation and heat rejection module can be used alone to provide complete payload support services and installation provisions for 250 ft<sup>3</sup>/600 pounds of experiments. Added experiment installation provisions and fuel cell reactants can be readily provided by the addition of the delta energy module.

# APPS GENERAL ARRANGEMENT

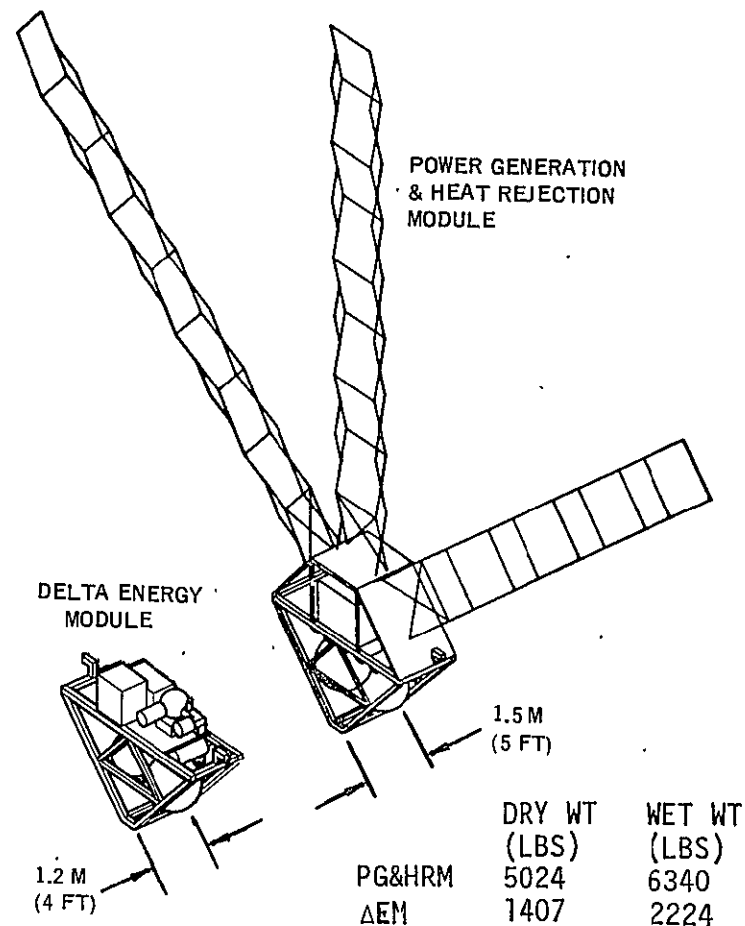
## *Dual module configuration improves mission-of-opportunity capture*

### POWER GENERATION & HEAT REJECTION MODULE

- o COMPLETE POWER GENERATION SUBSYSTEM
- o ONE SET (HALF) REACTANT & PRODUCT WATER TANKS
- o COMPLETE THERMAL CONTROL SUBSYSTEM
- o COMPLETE DATA MANAGEMENT & CONTROL SUBSYSTEM
- ✓ o 250 FT<sup>3</sup>/600 LB EXPERIMENT INSTALLATION ALLOWANCE
- o CAN BE USED SEPARATELY AS MISSION SUPPORT EQUIPMENT

### DELTA ENERGY MODULE

- o ONE SET (HALF) REACTANT & PRODUCT WATER TANKS
- ✓ o 400 FT<sup>3</sup>/1400 LB EXPERIMENT INSTALLATION ALLOWANCE
- o MUST BE USED WITH POWER GENERATION & HEAT REJECTION MODULE

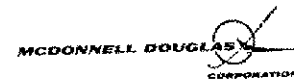


THIS PAGE INTENTIONALLY LEFT BLANK

AUXILIARY  
PAYLOAD  
POWER  
SYSTEM

## SCHEDULE

PRECEDING PAGE BLANK NOT FILMED.



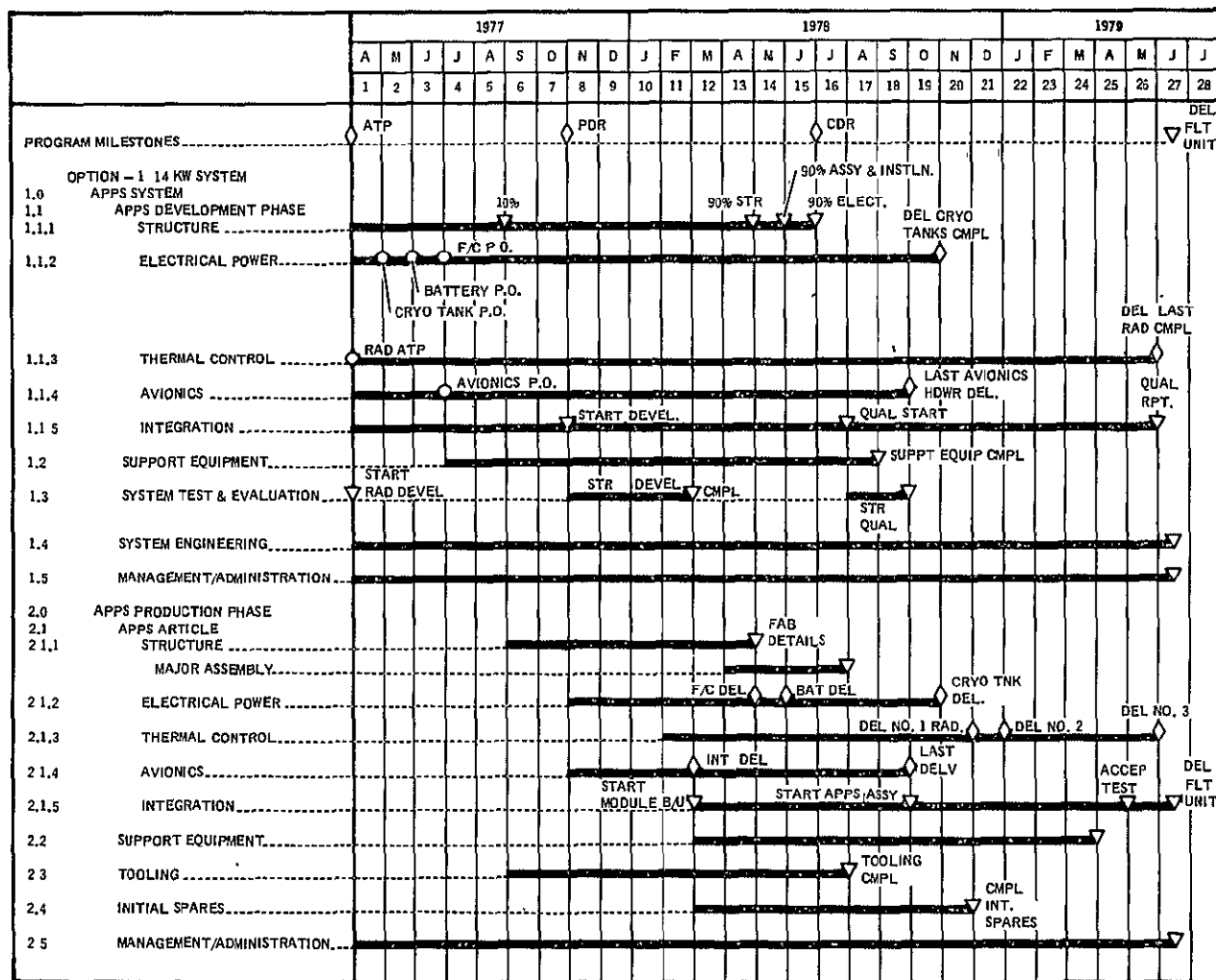
## MASTER PROGRAM SCHEDULE

A master schedule for design, development, production, and test of the APPS is shown on the facing page. The pacing item affecting delivery of the flight unit is the APPS radiator. Program milestones are shown at the top of the chart. Delivery of the flight unit in the second quarter of 1979 is compatible with the desired first flight in 1980.

AUXILIARY  
PAYLOAD  
POWER  
SYSTEM

# MASTER PROGRAM SCHEDULE

*The APPS radiator is the pacing item affecting APPS delivery*



MCDONNELL DOUGLAS

CORPORATION

THIS PAGE INTENTIONALLY LEFT BLANK



AUXILIARY  
PAYLOAD  
POWER  
SYSTEM

# VERIFICATION

~~PRECEDING PAGE BLANK NOT FILMED~~

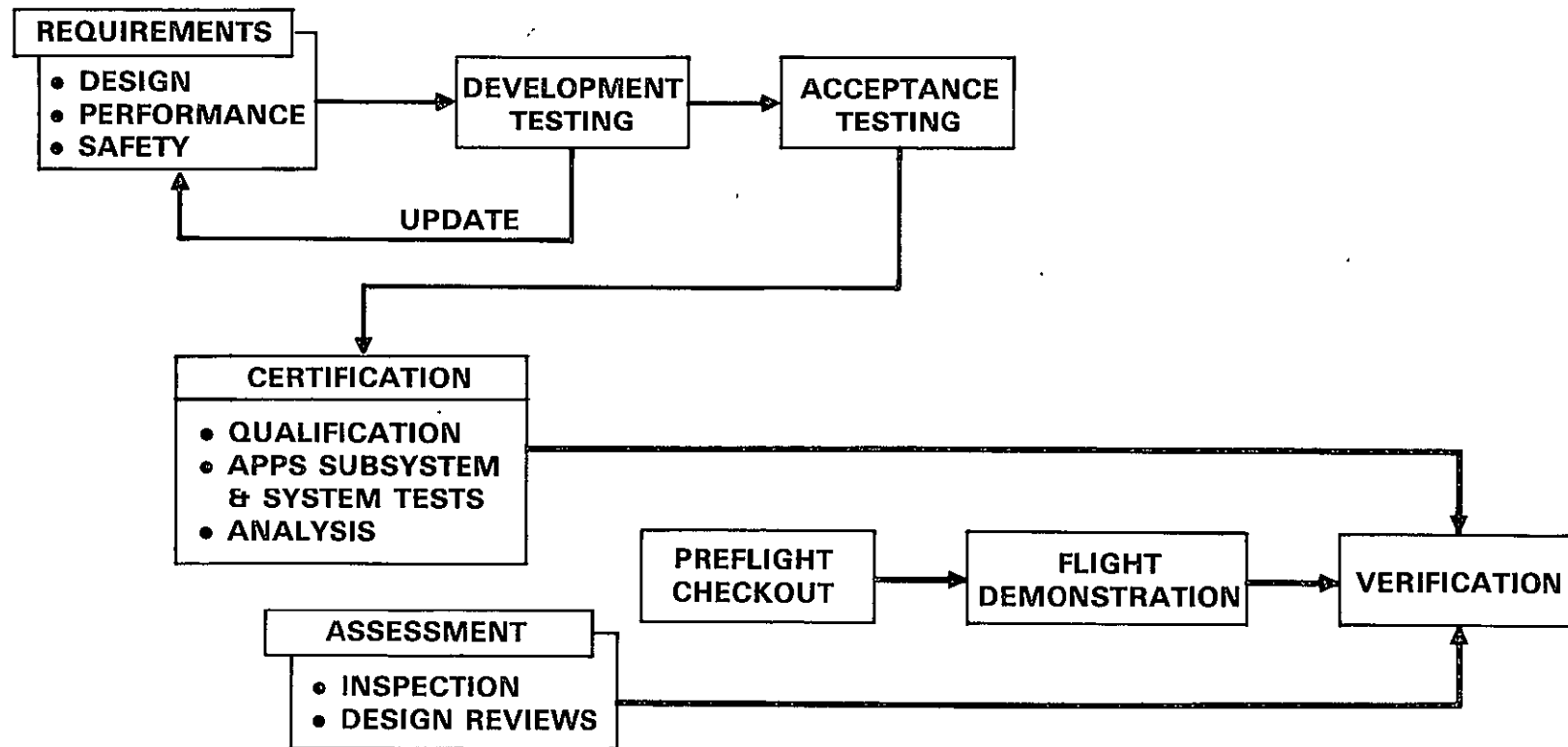


## APPS VERIFICATION APPROACH

The APPS verification approach will be to implement a program that economically determines that the APPS meets all design, performance, and safety requirements. Primary objectives to be accomplished by this approach will include: (1) support to development of design, (2) certification that the design of APPS components and subsystems meet performance requirements, (3) verification that the performance of combined APPS subsystems meet established requirements, and (4) demonstration of the acceptability and readiness for intended use of the deliverable APPS hardware. These objectives will be accomplished by analysis, test or combinations of these. Where analysis does not provide reasonable assurance of design adequacy, development testing will be implemented. Acceptance testing to verify readiness of hardware for delivery to the customer, will be conducted at all levels, from components supplier to the system level. Certification planning will assure that necessary data from qualification, subsystems and system test, and analysis are available to substantiate performance requirements, with minimum testing. Preflight subsystem/system level acceptance test and checkout will verify the readiness of the APPS for its intended use.

# APPS VERIFICATION APPROACH

*Verification is the implementation of a program that economically determines the APPS meets all design, performance and safety requirements*



## DEVELOPMENT TESTS

The tests listed on the facing page summarize the major development tests that are required. These tests support the design and analysis process in the development of the individual component and/or assembly as it relates to the performance of its subsystem.

## DEVELOPMENT TESTS

***Development tests support the design and analysis process***

### **ELECTRICAL POWER SUBSYSTEM**

- INVERTER SUPERVISORY PANEL BREADBOARD TEST
- BATTERY CHARGER BREADBOARD TEST
- INVERTER CURRENT PROTECTION DEVICE TEST

### **THERMAL CONTROL SUBSYSTEM**

- FC-40 COOLANT PUMP PACKAGE TEST
- COLD PLATE PANELS TEST
- INTERFACE HEAT EXCHANGER TEST
- DEPLOYABLE RADIATOR ASSEMBLY COMPONENTS TEST

### **AVIONICS SUBSYSTEM**

- SIGNAL CONDITIONER TEST
- COMPUTER INTERFACE MODULE TEST
- INSTRUMENTATION SENSOR TESTS (IF APPLICABLE)
- SOFTWARE TESTS
- EMI TESTS

### **STRUCTURAL/MECHANICAL SUBSYSTEM**

- STATIC/PROOF TEST OF APPS/ORBITAL INTERFACE
- THREE AXIS VIBRATION TEST OF FLIGHT APPS

### **GROUND SUPPORT EQUIPMENT**

- INTEGRATED WITH SUBSYSTEM TESTING (WHERE PRACTICAL)

## QUALIFICATION TESTS

Usage of Shuttle type components on the APPS will minimize qualification costs. The use of such components has been maximized in the APPS baseline design where possible. New equipment to be developed specifically for APPS usage will require full qualification, while modified equipment may require only delta qualification.

## QUALIFICATION TESTS

***Demonstrate the realization of design  
and performance requirements***

### **ELECTRICAL POWER SUBSYSTEM**

- NEW EQUIPMENT — INVERTER SUPERVISORY PANEL
- DELTA QUAL TEST — SHUTTLE HARDWARE
  - INVERTER
  - BATTERY CHARGER
  - ELECTRICAL DISTRIBUTOR
  - PYRO RELAY PANEL

### **THERMAL CONTROL SUBSYSTEM**

- NEW EQUIPMENT — RADIATOR MODULE
- DELTA QUAL TEST
  - FC-40 COOLANT PUMP PACKAGE
  - DEPLOYABLE RADIATOR (MECHANICAL  
OPERATION)

### **AVIONICS SUBSYSTEM**

- NEW EQUIPMENT —
  - SIGNAL CONDITIONER
  - COMPUTER INTERFACE MODULE
- SOFTWARE

## ACCEPTANCE AND CHECKOUT TESTS

Pre-delivery acceptance tests consisting of performance/functional tests will be conducted at the vendor's facility on all individual subsystem components, where required and as defined by the APPS test plan. After buildup into an assembly, each subsystem will be subjected to performance tests to verify satisfactory operation.

Integrated subsystem testing will be accomplished to verify APPS subsystem functional compatibility. The completed APPS will be tested to verify that the system is acceptable for integration with other interfacing systems, i.e., orbiter, spacelab, SPA experiments. APPS launch readiness will be verified by conducting subsystem/system level functional checks similar to those used during acceptance tests.



## ACCEPTANCE AND CHECKOUT TESTS

*Verify readiness for delivery and customer usage*

### APPS SUBSYSTEM ACCEPTANCE TESTS

- HARDWARE TESTS CONDUCTED AT VENDOR
- SUBSYSTEM PERFORMANCE TESTS
- SUBSYSTEM INTERFACE VERIFICATION

### APPS SYSTEM ACCEPTANCE TESTS

- INTEGRATED SUBSYSTEM TEST
- SYSTEM PERFORMANCE TESTS
- APPS INTERFACE VERIFICATIONS
  - TO: ORBITER, SPACELAB, SPA EXPERIMENTS

### APPS CHECKOUT TESTS

- VERIFICATION OF LAUNCH READINESS
- SAME TESTS AS FOR ACCEPTANCE
  - TEST EQUIPMENT AND GSE
  - PROCEDURES

## VERIFICATION PLAN SUMMARY

The verification program approach is tailored to demonstrate that APPS subsystem performance requirements have been satisfactorily achieved at minimum cost and expenditure of hardware. Shuttle derived hardware will be used to the maximum extent possible. Component/hardware performance will be verified where possible by design and supporting analyses. Only those development tests will be conducted that need to substantiate any design for its intended usage.

## VERIFICATION PLAN SUMMARY

***APPS verification will be accomplished at minimum cost***

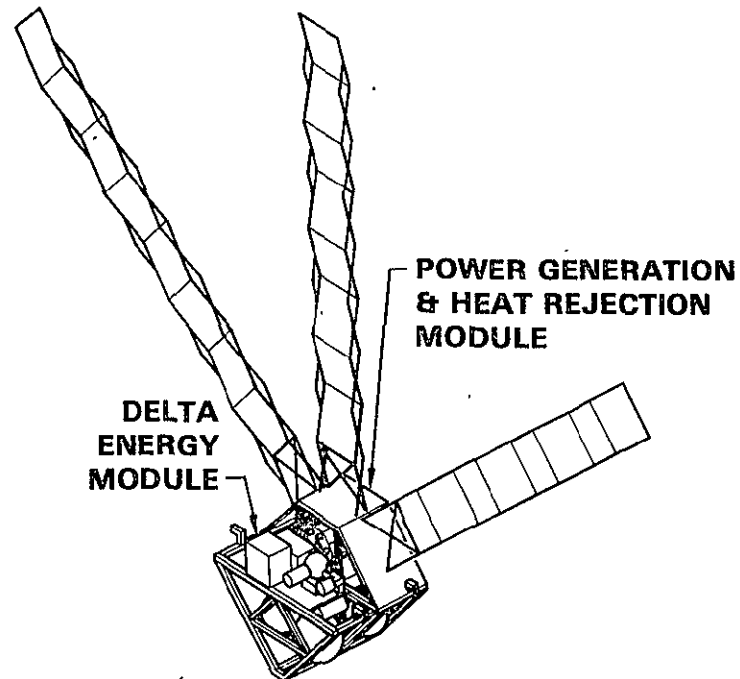
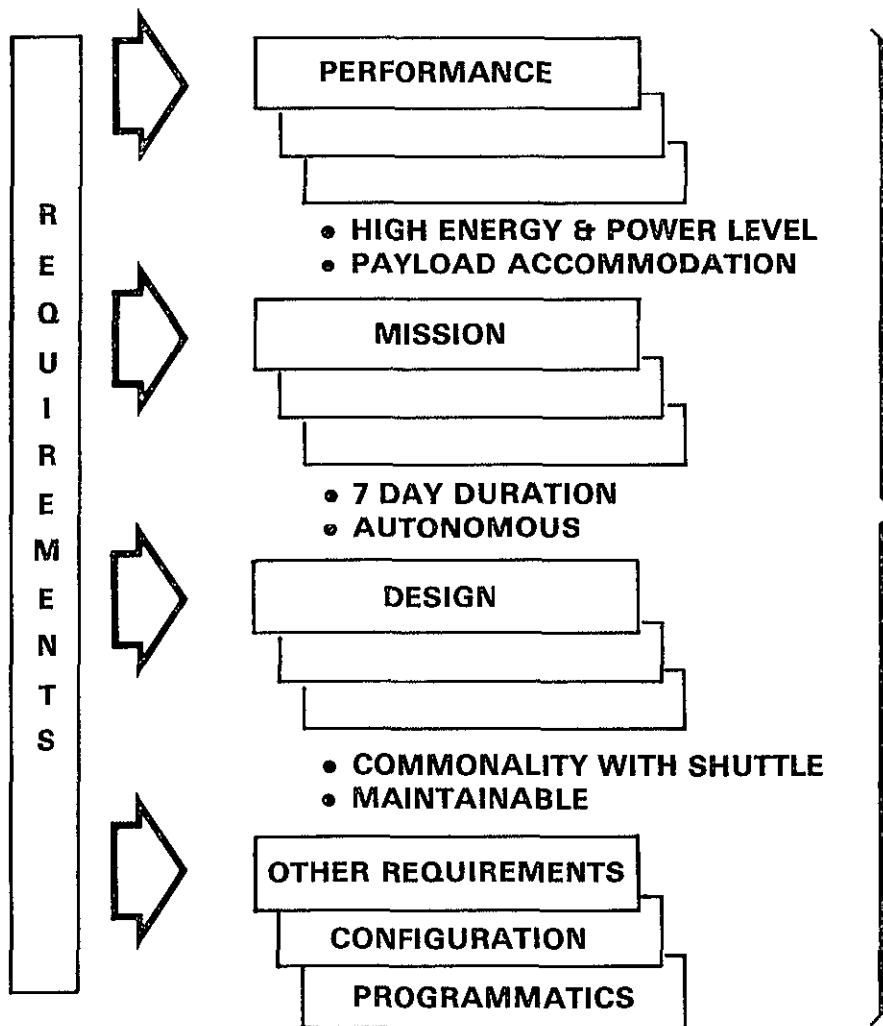
- **ALREADY DEVELOPED AND QUALIFIED HARDWARE WILL BE UTILIZED TO THE MAXIMUM EXTENT PRACTICAL**
- **HARDWARE PERFORMANCE REQUIREMENTS WILL BE SATISFIED BY DESIGN AND SUPPORTING ANALYSIS WHERE POSSIBLE**
- **ONLY THOSE DEVELOPMENT TESTS NEEDED TO SUBSTANTIATE A DESIGN FOR ITS INTENDED USE WILL BE CONDUCTED**

## SUMMARY

The APPS design is modular to accommodate a variety of payloads and to permit capture of missions of opportunity. SPA experiment payloads of up to 2000 pounds in weight with a total volume less than 650 ft<sup>3</sup> can be accommodated assuming both the power generation and heat rejection module, and delta energy module are installed in the Orbiter payload bay. Power capability is 14 kilowatts, with a net payload power of 10 kilowatts after allowing for APPS housekeeping loads. Stored fuel cell reactants are sufficient to generate 1932 kilowatt-hours of energy. Net payload energy is 1300 kilowatt-hours. The design philosophy has been to minimize the impact on Shuttle operations by providing for autonomous operation where possible.

## SUMMARY

*The evolved APPS configuration provides high performance and mission versatility for a variety of SPA experiments*



### SPA EXPERIMENT ACCOMMODATION:

- WEIGHT — 2000 LB
  - VOLUME — 650 FT<sup>3</sup>
- POWER — 14 KW (CONTINUOUS)  
ENERGY — UP TO 1932 KWH  
HEAT REJECTION — DEPLOYABLE RADIATOR  
SIZE — 9 FT; 5 FT  
LIFE — 100 MISSIONS

**MCDONNELL DOUGLAS ASTRONAUTICS COMPANY - EAST**

*Saint Louis, Missouri 63166 (314) 232-0232*

